TRANSACTIONS
OF THE
SOUTHERN SURGICAL ASSOCIATION

MEETING HELD AT HOT SPRINGS, VA.
DECEMBER 4-6, 1945

ADDRESS OF THE PRESIDENT

THE TRANSYLVANIA MEDICAL LIBRARY*

CHARLES A. VANCE, M.D.
LEXINGTON, KY.

I WOULD BE VERY REMISS in my obligation to you if I did not first thank you for the very great honor you have bestowed on me. To be elected your President is the greatest honor that can come to any surgeon, and I am expressing to you my very sincere thanks and appreciation.

Our association has shown considerable interest in surgery in Kentucky. At the Lexington meeting in 1930 there was conducted a pilgrimage to the tomb of Ephraim McDowell, in Danville, and addresses were made by our fellow members, Dr. Urban Maes and Dr. F. G. DuBose, and a wreath was placed on the grave. During that meeting a number of Fellows who visited the Transylvania Medical Library, were so impressed by the priceless collection of old medical volumes contained in the library that the following resolution was presented by Dr. J. M. T. Finney: "That we desire, first of all, to felicitate the University upon being the repository of such a unique collection. At the same time, we are greatly disturbed by the fact that, unfortunately, this collection is not housed in a fire- and theft-proof building. Feeling deeply that the loss to the profession at large, as well as in that of the Southland, which this association more closely represents, would constitute an irreparable loss, the Southern Surgical Association offers its services, in coöperation with the proper authorities, toward securing adequate protection.

To this end, it is moved that the President be instructed to appoint a com-

---

mittee for this purpose." This matter was referred to the President and the Council, and a committee from the association was appointed. This committee included Doctors Abell and Vance, from Kentucky, and several others. A meeting or two was held but nothing much was done.

Personally, I have been interested in Transylvania University all my life. My grandfather, Robert A. Gibney, graduated at the Transylvania Medical Department in 1836. His Inaugural Dissertation, as it was called then, was on "Respiration," and my great uncle, my grandfather's brother, Thomas Carson Gibney, graduated there in 1841. His Inaugural Dissertation was on "Oscultation and Percussion." And a number of other members of my family attended and graduated at Transylvania, and I graduated there in 1900, so you see I have a personal interest in Transylvania.

Dr. Robert Peter says in his history of the Medical Department of Transylvania: "That the History of Medicine and of the earliest medical men in Kentucky clusters around the name of Transylvania University."

In 1780, the State of Virginia placed 8,000 acres of escheated land within the County of Kentucky into the hands of 13 trustees "for the purposes of a public school or seminary of learning," that there "might, at a future day, be a valuable fund for the maintenance and education of youth: it being the interest of this Commonwealth always to promote and encourage every design which might tend to the improvement of the mind and the diffusion of knowledge, even among the most remote citizens, whose situation, a barbarous neighborhood and a savage intercourse, might otherwise render unfriendly to science."

In 1783, after Kentucky had become a District of Virginia, the General Assembly, by a new amendatory act, reëndowed this public school with 12,000 acres of escheated lands and gave to it all the privileges, powers, and immunities of any college or university in the State under the name of "Transylvania Seminary." This was located permanently in Lexington on a plot of land donated by the City of Lexington in 1793, and Rev. James Moore was the first acting President in 1791. The name was derived from the Transylvania Land Company which Henderson had started several years before for the sale of lands in Kentucky.

Dissatisfaction with the conduct of Transylvania Seminary, among some of the members of the Board of Trustees, caused them to leave that school and obtain, in 1796, a Charter from the Legislature of Kentucky for a new institution of learning which they could more exclusively control. This was the Kentucky Academy, of which the Rev. James Blythe was made President. After two years of separate existence these two institutions, with the consent of the trustees of both, were united, in 1798, by Act of the General Assembly into one—"For the promotion of public good and learning," under the name of Transylvania University. This consolidation was made under the original laws which governed the Transylvania Seminary, as enacted by the General Assembly of Virginia.

Under this act of December 22, 1798, the University was organized by the appointment of the Rev. James Moore, of the Episcopal Church, as the first

acting President, with a corps of professors, and then, for the first time, in the Mississippi Valley and the West the effort was made to establish a Medical College.

Early in 1799, at the first meeting of the Board of Trustees of the new Transylvania University they instituted the Medical Department of Transylvania, which subsequently became so prosperous and so celebrated, by the appointment of Dr. Samuel Brown as Professor of Chemistry, Anatomy, and Surgery, and Dr. Frederick Ridgely as Professor of Materia Medica, Midwifery and Practice of Physic. Dr. Brown qualified as Professor October 26, 1799, and Dr. Ridgely the following month.

Doctor Brown was authorized by the Board to import books and other means of instruction for the use of the medical professors to the amount of 500 dollars, a considerable sum in those days, and he and his colleagues were made salaried officers of the University.

At a meeting of the Board of Transylvania Seminary, in 1784, they acknowledged the gift from the Rev. John Todd, of Louisa, in Virginia, of a Library and a Philosophical apparatus for the encouragement of science in this institution. There is frequent mention in subsequent minutes of the Board of its appropriation of money to add to the Library to which, it is evident, they attached great importance. In addition to the 500 dollars given to Doctor Brown for the purchase of medical books, 600 dollars


FIG. 1.—First building of Transylvania Medical Department. Built in 1827 and taken over by the City of Lexington in 1839 and the rear part of it burned in 1854. The front part is still standing.

was appropriated for the purchase of law books. Thus, was the beginning of Transylvania Medical Department and the Transylvania Medical Library.

Doctors Brown and Ridgely taught such students as came to them but no attempt was made to build a medical school building and conduct classes which would lead to degrees in medicine until the school was reorganized. When this was done, in 1815, Dr. Benjamin Winslow Dudley was appointed Professor of Anatomy and Surgery, and a number of other distinguished physicians were appointed to its faculty, and it became one of the best known medical colleges in the United States.

The first graduating class of the reorganized school was in 1818, and the first graduate was John Lawson McCullough, who received his A. B. degree, in 1809, from the College of Liberal Arts of Transylvania University, and his M. D. degree, in 1818, from the Medical College.

In 1820, the sum of $17,000.00 was furnished to Dr. Charles Caldwell, with which to purchase books in Paris for the Medical Library. This money was raised from the City of Lexington and the Kentucky Legislature and from private sources, and was given to Dr. Caldwell personally.

He writes in his autobiography: "The time of my arrival in Paris was uncommonly and unexpected propitious for my purpose. The ravages and waste-laying of the French Revolution had not entirely passed away. Toward the close of the catastrophe the libraries of many wealthy and literary persons had found their way to the shelves of the book seller. No sooner was I apprised of these precious repositories than I procured permission to ascertain of what they consisted. Some of them were stored with venerable literature. I found, and purchased at reduced prices, no inconsiderable number of the chemists and the choicest works of the Fathers of Medicine from Hippocrates to the revival of letters. Works which in no other way, and perhaps at no other time could have been collected so readily and certainly on terms so favorable in either Paris or any other city in the world."

Again, in 1839, Dr. Robert Peter and Dr. J. M. Bush spent $11,000.00 in London and Paris for books and apparatus for the Medical College. These trips by Doctors Caldwell, Peter and Bush procured for the University about 10,000 valuable medical books and also specimens and apparatus for teaching and various plates and pictures and several microscopes and a camera made by Louis J. M. Daguerre. He was a French painter and inventor of the Daguerre process method of obtaining pictures by the action of sunlight. His perfected process was communicated to the Academy of Sciences on January 9, 1839. According to reports in the Transylvania Library the Daguerre camera was first used in New York, August, 1839, and they were using it at Transylvania University in Lexington in October, 1839. The original bills and expense accounts of these two trips to Europe by Doctors Caldwell, Peter and Bush are on file in the Library.

Dr. Thomas D. Mitchell said, in his valedictory to the graduating class in 1839-40, in addition to describing lecture halls and courses of instruction and

Fig. 2.—Second Medical Building built in 1839 and burned in 1865 while being used as a Government Hospital by the United States Army troops.
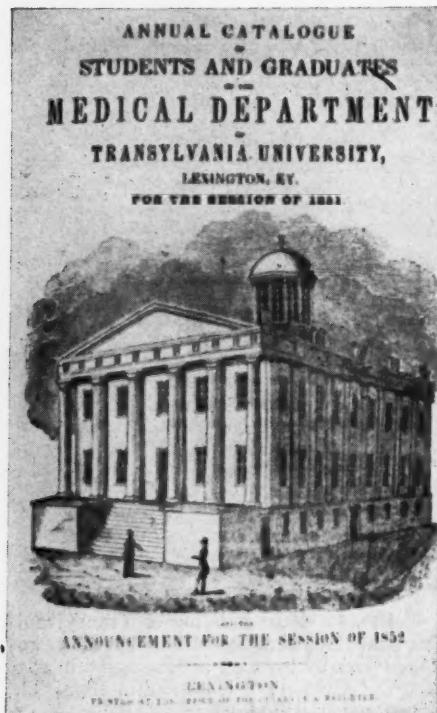
interesting cases shown and operated upon: "A well-lighted library apartment 30 x 60 feet and 15 feet in height, with the richest collection of splendid and rare plates, standard medical works in the living and dead languages, European or American periodicals that can be found in any similar institution in the

THE PRINCIPAL BUILDING OF TRANSYLVANIA UNIVERSITY, INSCRIBED TO PRESIDENT HOLLEY.
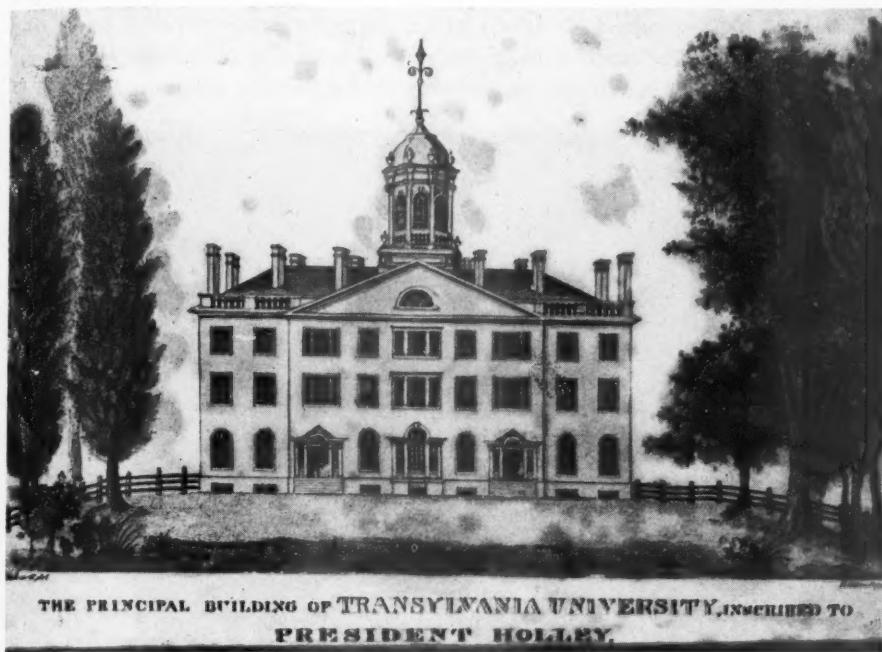
Fig 3.—Main Building Transylvania University built in 1818 and burned in 1829.

Fig. 4.—Morrison College built in 1833 by Gideon Shryock and is still standing.

country, will attract your notice. Arranged according to their various affinities, not less than 7,000 volumes will be found in this department; and these culled from the best and most ample sources, so as not to leave a single chasm, that may not be filled up by its annual income. In this, and the contiguous rooms, the most accurate and delicate paintings of medicinal plants the Capitol of France could furnish, will also find a conspicuous place. I need not tell you that these exquisite paintings are true to life, for you have already satisfied

yourselves that such is the fact. In all, there are 51 of these drawn and painted after the living specimens in the Jardin des Plantes, by the ablest Parisian artists.

They are the only collection of the kind in the country. In near association will be seen the drawings and paintings for the surgical, medical, obstetrical and chemical departments, designed to facilitate the studies of the pupil and well-adapted for the illustrations of the several teachers. Twenty-eight of the most accurate pictures representative of morbid structure, made by the ingen-
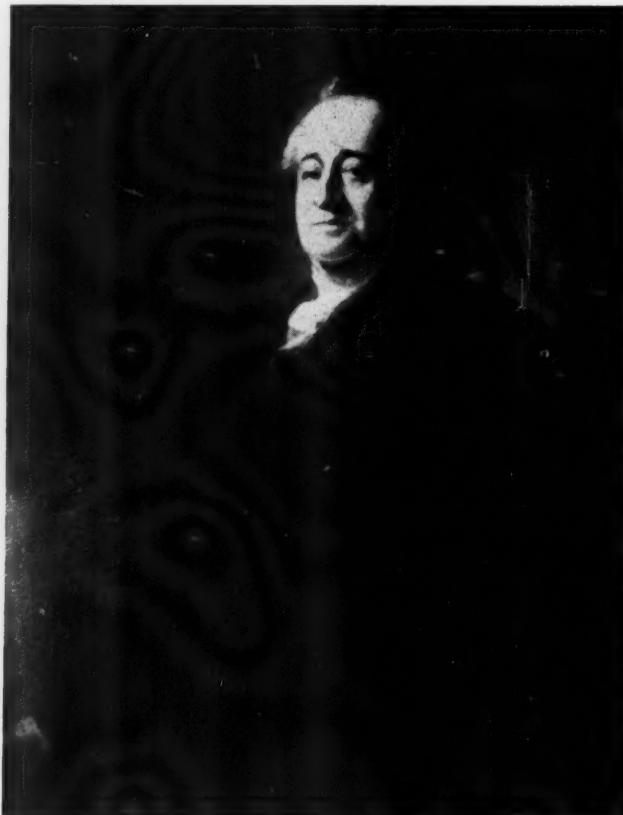

FIG. 5.—Dr. Samuel Brown.

uous Thibert, whose efforts have received the highest praise from the prince of pathologic anatomists Cruvalhier, are already in our possession.

These, as you know, exhibit, most accurately, the various changes induced by disease in the most important organs, and greatly aid the professor of Theory and Practice in the prosecution of his duties. But these are only the beginning of our means in this department, since, at least, two of one are in possession of the process as well as the test for extending the number, so as to embrace every shade of morbid anatomy, that may be available in teaching practical medicine. The fair and varigated models in wax of the disease of the genital organs and especially of the female, whose excellence could not be

fully set forth without trespassing greatly on your patience, are all regarded as of inestimable value; and having been procured exclusively from a private cabinet are without a parallel either in this country or any other. Already, you have admired a few of the beautiful preparations, attended to and recently displayed, as well as our present means would allow. But arranged as the whole will be in the new museum.

With the most favorable light for this fine exhibition you will behold a collection far in advance of any in the great West, and excelled by none save that of the present school in Philadelphia. In close proximity to this is, as well as to the ampitheater, will be found the spacious dissecting room furnished with every appendage that can give interest or value to that department. The gallery of chemical and philosophic apparatus so arranged as to be in view of the class while seated in the hall or so inaccessible as to be more minutely inspected at leisure will claim a special notice. Its large model steam engine; its apparatus for solidifying carbonic acid gas; its multiplied and greatly diversified electrical, galvanic and magnetic arrangement; its splendid air pumps; its mounted concave mirrors; its compact and highly finished locomotive, with a hundred other beautiful works of the first artists in Europe or America—all calculated to augment the facilities of chemical instruction, together with mineralogic and geologic cabinets, will convince the most skeptical that nothing is wanting to make up the full inventory of a perfect medical college."

FIG. 6.—Dr. Charles Caldwell.

From 1819–1826 the distinguished Botanist, C. A. Rafinesque, was professor of Natural History at Transylvania University, and for part of that time was Librarian. Mrs. Charles F. Norton says: "It is probably owing to his influence that the library is so especially rich in works of Botany and Natural History."

It is impossible to go into details as to the books contained in the fine old collection, but as a result of the enthusiasm and generosity of those who have had charge of its destinies in the early years it became a most valuable adjunct to the work of the institution, and remains to this day one of the most notable collections of its kind in the country. And many authorities and investigators have visited there and used the Library in their research.

When Albert H. Buck, who was Professor of Diseases of the Ear at Columbia University, was writing his work on "The Dawn of Medicine" this book being a continuation of his former book "The Growth of Medicine," he had failed to find trustworthy information on his first visit to Europe and on

another trip he could not find what he wished and he was disposed to abandon the undertaking. This news item was published in a scientific journal and Mrs. Charles F. Norton, the Librarian of Transylvania College saw it and wrote him that he might find his information in the Transylvania Library. He rather doubted her statements but he wrote her that he would submit a list of 25 books he needed to see if she had any of them and she found 23 out of the 25. She then sent him another list of 100 French, English and Latin books and wrote him that Transylvania University would be glad to allow him to use the material in the Library. He then came to Lexington and stayed seven months, most of the time in the Transylvania University Library, and finished his book.
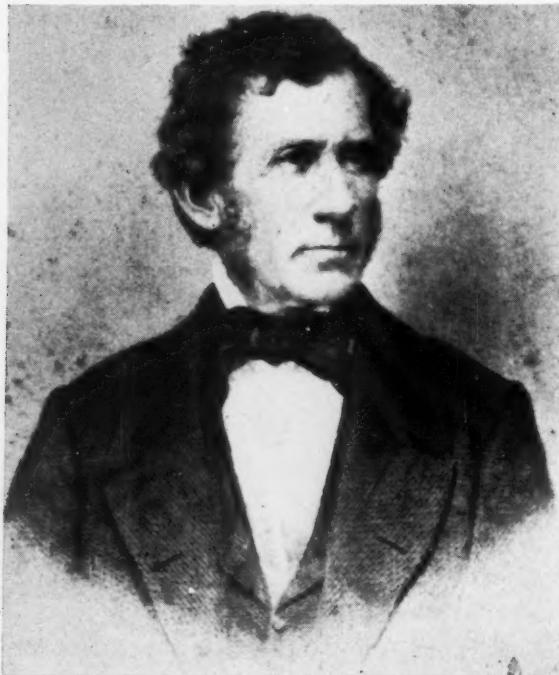

FIG. 7.—Dr. Daniel Drake.

A most interesting feature in the old catalogues and lists of pupils, is that after the pupil's name and address is the name of the physician who was his teacher or preceptor.

Each graduate wrote an Inaugural Dissertation, or Thesis on his graduation. All of these are bound in volumes and are kept in the Library, and there are 1,860 of them on file, and they are most interesting and a great many have been consulted by students of medical history and descendants of the writers.

In 1827, professors and citizens of Lexington formed a joint stock company, whereby they raised enough money to erect a Medical Hall, which was used until 1839, when the City of Lexington built a new hall for the Medical School, taking one old hall over for municipal purposes. The second Medical Hall was destroyed by fire during the Civil War in 1865, after it had been taken over by the United States Government as a hospital.

The Medical School continued to grow and flourish, and Dr. Thomas D. Mitchell said about it the following: "That for its vigorous prosperity and the rapid increase of its classes the Medical School of Transylvania is without a parallel, certainly, in the United States there is nothing comparable to it. This is the highest eulogy the institution can receive. The most eloquent and forcible language in praise of it would be spiritless and feeble contrasted with the power of the foregoing figures."

In the years, from 1815–1859, when the last class was graduated, they had 6,456 students and graduated 1,881 Doctors of Medicine, and in the last page of the Trustees' Book, of that year, are listed the names of the students and graduating class, and signed by Robert Peter, Dean, who wrote after his signature: "And so ended the first cycle of the Medical Department of Transylvania University."

R. T. Durrett, President of the Filson Club, of Louisville, wrote the introduction for the preface on the "History of the Medical Department of Transylvania University," by Dr. Robert Peter, and closed with the following:

"There is in our nature something like the love of the relic which makes us revere the memory of Transylvania University. Early in the year 1799 a Medical Department was attached to this University, which was the first Medical College in the great Mississippi Valley and the second in the whole United States. The Medical Department of the University of Pennsylvania antedated it, as it antedated all others afterward established in any part of our vast domain. We can

FIG. 8.—Dr. Benjamin Winslow Dudley—From Jouett portrait hanging in Morrison College Chapel.

not, like our English cousins, go back along the pathway of centuries to the colleges of Oxford and Cambridge, and revere them for their age; We have nothing in our country that partakes of such age. We are a young people in a young country, and our Transylvania Medical College was old enough, from our standpoint, to be crowned with hoary years. We revere it as the first Medical College on this side of the Alleghanies. We revere it for the efforts it made to prepare our young physicians to cope with the diseases that afflicted our people. We revere it for the good name it gave our State in the fame it acquired. We revere it for the success of Professor Brown in introducing vaccination in advance of its discoverer, for the brilliant and numerous operations in lithotomy by Professor Dudley, and for the noble efforts of others of its professors in prolonging human life and mitigating its pains. What it did in the day of its glory is written in its annals and he who considers them

489

seriously will hardly doubt that the Medical College of Transylvania University is worthy of its record."

It would be appropriate to mention here that Colonel Durrett, whose statement I have just read, was not entirely familiar with the facts about the first Medical Schools. According to the best information I can obtain the first Medical School in the colonies was that of Philadelphia, founded in 1765; then followed Kings College in New York, 1767, and Harvard Medical School, Boston, 1783; Dartmouth at Hanover, New Hampshire, 1798, and Transylvania Medical College organized in 1798, and started in 1799, but was reorganized, as I have stated, in 1815, and graduated its first class in 1818, and continued until 1859.

Frederick Ridgely (1757-1824) was a native of Elk Ridge, Anne Arundel County, Maryland. He had begun the study of medicine when the Revolution began, and he at once joined a corps of riflemen from Virgina and Maryland as a surgeon. He served in the army throughout the war with the exception of two brief periods, one of which he devoted to medical study in Philadelphia, and during the other he served as surgeon to a privateer which was captured by the British in Chesapeake Bay, Ridgley escaping by jumping overboard and swimming ashore. After the war he practiced for a time in Maryland, and then moved to Lexington, Kentucky. In 1799, he was appointed professor of Materia Medica, Midwifery, and Physics in Transylvania University.

FIG. 9.—Dr. Ethelbert Ludlow Dudley.

He was an excellent teacher and, in 1799–1800, he delivered to the small class of medical students, then in attendance, a course in Public Instruction, and he continued to do that for a number of years, and, in addition, he had many office pupils, among them being Dr. B. W. Dudley and Walter Brashear. Dr. Dudley always spoke with warmth and esteem of his scholarly and urbane preceptor as a physician whose high culture of mind and educated moral tone reflected dignity upon his profession.

Although Walter Brashear (1776–1860) was never a teacher nor a writer, he deserves mention in this association as one of the men who shed luster on surgery in Lexington, Kentucky. In 1806, while practicing at Bardstown, Kentucky, he amputated successfully through the hip joint, 16 years before the same operation was performed by Valentine Mott.

Samuel Brown (1769–1830) was a native of Virginia. His father, a Presbyterian clergyman, sent him to Dickinson College, at Carlisle, Pennsylvania.

FIG. 10.—Dr. Robert Peter, age 34. Miniature painted by Chazal in Paris in 1839.
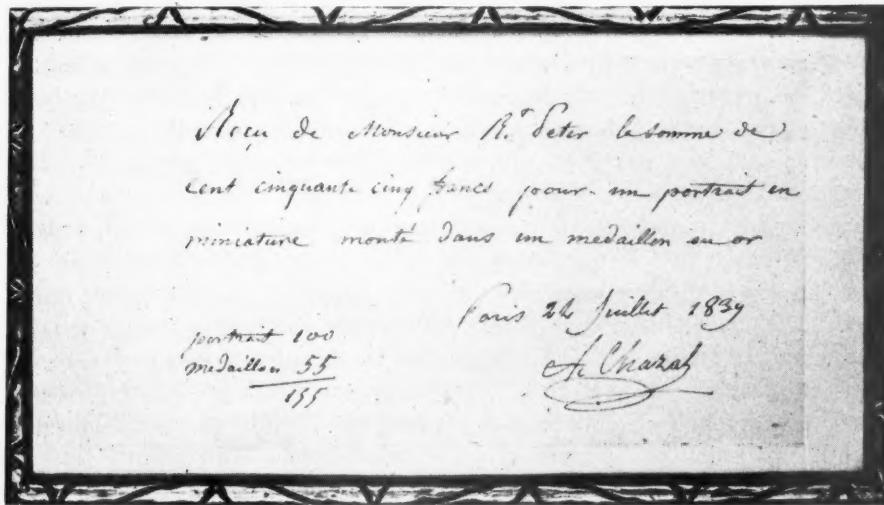
FIG. 11.—Receipt for miniature and medallion.

After receiving his A. B. degree from that institution, he studied medicine first with his brother-in-law, Dr. Humphreys at Staunton, Virginia, and then

as a private pupil under Dr. Benjamin Rush, in Philadelphia. He then went to Edinburgh but returned to the United States without having taken a degree. In 1797, he settled at Lexington, Kentucky, and two years later was appointed as Professor of Chemistry, Anatomy and Surgery at Transylvania University. As early as 1802 he had vaccinated more than 500 persons for the prevention of smallpox, when in New York and Philadelphia, physicians were just making their first experimental attempts. The virus he used was taken from its original source, vesicles from the cow, and was used in Lexington even before Edward Jenner could gain the confidence of the people of his own country, England. As is well known, Jenner was ridiculed and persecuted, and it took him a good many years to convince the people and physicians about the truth of his reasoning and discoveries; Doctor Brown, however, accepted his reasoning and used vaccination early and as often as was necessary.

A curious anecdote was told of Dr. Samuel Brown by his nephew, the late Orlando Brown, of Frankfort, in a letter to Doctor Peter: "I remember once when talking of calomel, he, Doctor Brown, said he never would forget the first dose of it he gave a patient. It was looked upon as "The Hercules," and he used it accordingly. The case was desperate and he resolved to venture upon calomel and give a strong dose. He, accordingly, weighed out with scrupulous accuracy four grains, gave it to his patient, and sat up all night to watch its effects. The man got well and then Doctor Brown afterwards used calomel more freely. What would he have thought of the heaping tablespoonful doses frequently repeated *pro re nata,* or the pound of calomel taken in a day and the patient surviving, which characterized the cholera treatment of one of the later professors of Transylvania Medical School.

In 1802, Samuel Brown founded the famous Kappa Lambda Society of Aesculapius, a secret organization of medical students and physicians of which chapters were organized throughout the United States. The purpose of the Society was to elevate the standards of the profession and do everything honorable to promote the welfare of physicians in and out of the Society, and to abide implicitly by a stringent code of ethics that had been prepared for the guidance of the members in their intercourse with each other, and with society at large, and to promote the advancement of medical knowledge, but, unfortunately, quarrels and dissension among its members finally caused its dissolution. In 1826, the Society founded the North American Medical and Surgical Journal at Philadelphia, Pennsylvania with a most respectable body of editors —Dr. Hugh L. Hodge, Dr. Franklin Boche, Dr. Charles S. Meigs, Dr. B. H. Coates and Dr. Rene de la Roche. Shortly afterwards both in Philadelphia and New York City quarrels between doctors demonstrated the powerful influence which Kappa Lambda was exerting in medical matters. As a result the Society fell into disrepute and the Journal and Society itself passed out of existence in 1852. Dr. B. W. Dudley was listed as one of the members of the Kappa Lambda Society in 1803, before he went to the University of Pennsylvania Medical College in 1804. Dr. Chauncey D. Leake has published a most interesting history of the whole affair—"What was Kappa Lambda?"

Of all the Professors of the Medical Department Dr. B. W. Dudley stands

out as the most prominent. He was born in Spottsylvania County, Virginia, and his family moved to Lexington, Kentucky when he was very young. He began the study of medicine under Dr. Frederick Ridgely (1757–1854), who with Dr. Samuel Brown constituted the first medical faculty of Transylvania University. In 1804, Dudley entered the Medical School of the University of Pennsylvania from which he received the degree of M. D. While in Philadelphia he had as fellow students Daniel Drake, John Esten Cooke and William H. Richardson with all of whom he was closely associated in later years. In 1810, Dudley went abroad and passed four years in study under the leading men in France and England. He regarded Abernathy as the greatest of surgeons but Sir Astley Cooper as the most skillful and graceful of operators. While abroad he became a member of the Royal College of Surgeons, and it has been reported that Napoleon offered him the place held by Baron Larrey as his Surgeon in Chief. From 1815–1850, when he retired from the Medical Department of Transylvania University, Dudley taught Surgery and Anatomy, although, in 1844, he gave up the chair of Anatomy and continued as Professor of Surgery.

Dudley was especially renowned for his skill as a lithotomist. Stone in the bladder seemed to have been unusually prevalent in Kentucky in those days. Dudley used the lateral method and employed the gorget devised by Cline. He, thus, cut 225 persons for stones and only lost six of his cases.

Dudley was wont to attribute his success, in great part,, to the great care which he took in preparing his patients for operation. He laid great importance on the use of boiled water in operations. Dudley successfully ligated the subclavian artery for axillary aneurysm. In 1828, he published a report of successful cases in which he had trephined the skull for the relief of epilepsy due to pressure on the brain. Henderson says he is probably the first surgeon in the United States to perform this operation. He was an admirable teacher and dominated the affairs of the Medical School at Transylvania. He amassed a very considerable fortune, and he was very generous in his charitable contributions, and also to his students who needed help. After retiring Dudley lived in his country house "Fairlawn" near Lexington, where he succumbed to a stroke of apoplexy in his 85th year. Dr. Samuel D. Gross did not profess the same admiration of Dudley as did most of his contemporaries. He visited Lexington to see his work in 1841, and writes: "At the same time to which I refer he was at the height of his reputation as a surgeon. Dudley's lecture on the day of my visit was on the Anatomy of the Muscles of the Forearm, and a more puerile discourse I have never listened to. It would hardly have been creditable to a tyro in anatomy. Dudley was well skilled in the use of the knife, was an excellent mechanical surgeon, or in other words an operator. Of surgical pathology he knew little or nothing: Certainly his teaching was far in arrears of the existing state of the Science.

His lectures on surgery, however, were always interesting, from the fact that they abounded in practical matter, the result of wide and ripe experience. His forte was lithotomy, in which he was for a long time *facile princeps*. It is said that he performed lithotomy 225 times, with the loss of only six or seven

cases. I have never, however, given credence to this statement because it was not verified by statistics. Dudley kept no record of his cases, of their sex, age, residence or of their condition before or after the operation. As most of his patients came from a distance, the men all lodged in one building, which was in charge of an ignorant steward. This man acted as nurse and when interrogated about the number of cases operated upon in any given time he helplessly raked his brain for an answer. Dudley did some good work in the ligation of arteries, chiefly limited, however, to those of the neck, and he may be regarded as the pioneer for the cure of epilepsy dependent upon injury of the skull, in which his success was remarkable. Dudley was one of those men who never
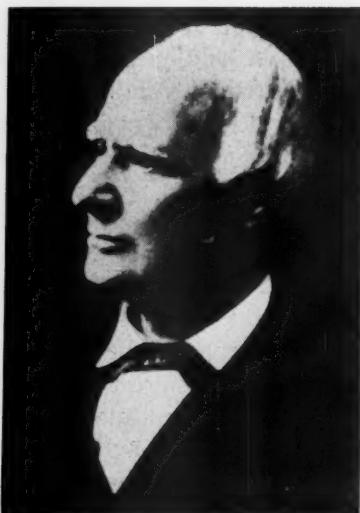

FIG. 12.—Dr. Robert Peter as an elderly man.

FIG. 13.—Portrait of Constantine A. Rafinesque.

correct the deficiencies of their early education. His style as a writer was execrable and his thoughts were clothed in ungrammatical English. Some of his letters would have disgraced a school boy."

Many interesting stories have been told about Dudley. He was worshiped by his students and beloved by his patients and the townspeople of Lexington, but, at times, there was great dissension among the members of the faculty and Dudley seems to have had his share of the quarrels and bickerings among them. One of his collateral descendants has told me that the family have always understood that he was a very kind hearted man and that he would do anything for his friends, and patients, and family, but that he was red-headed, and very impulsive and explosive when he was questioned or became irritated. One of the most interesting of the stories about him was that of the duel between him and Richardson. Dr. C. C. Graham, in his letters to Dr. Robert Peter, writes very vividly about it. He says that two drunken Irishmen had a knock-down and drag-out fight, and one fell and struck the back of his head against the curbstone and later died of concussion of the brain, and Dudley and Drake were summoned by the coroner to examine the case and testify before the jury.

Drake refused to attend but Dudley did testify and gave his opinion. Afterwards, Drake insinuated that the circumstances did not justify Dudley's decision. Before this Dudley and Drake had had disagreements and quarrels and Drake had written several pamphlets appealing to the "Justice of the Intelligent and Respectable People of Lexington." Dudley had answered them and charged that he, Drake, had attempted to destroy the Medical College of Transylvania while he was a professor in the institution. The appeals of Drake and Dudley's accusations and answers to Drake were published in pamphlet form and some of these pamphlets can be seen now. They are very interesting. In Drake's second appeal he said, in the language of Dean Swift, I may exclaim: "Strange such a difference should be, Twixt tweedle-dum and tweedle-dee."

It seemed that he, Drake, was getting the better of the controversy, so Dudley sought satisfaction by challenging Drake to a duel. Drake declined but Richardson, as his friend, accepted Dudley's challenge. Doctor Graham in his letters described the very serious preparation by Dudley for the duel, and how Dudley brushed up on his marksmanship with a pistol for several weeks before the duel and at the time of it he wore a green great coat which he had purchased in Paris. This coat had large bright buttons on it and Graham cut these buttons off before he and Dudley went to the duel. In the duel Dudley's shot injured Richardson's "inguinal artery" and he

FIG. 14.—William A. Cowper—Anatomy of Humane Bodies. Published 1698.

would have bled to death but for Dudley's aid, who knowing where the artery passed over the ilium checked the blood with the pressure of his thumb while Richardson's surgeon ligated the vessel. After this duel Dudley and Richardson became very great friends.

From all of the literature and stories about Dr. Dudley he certainly must have been a great man and a great surgeon, although, he had his faults such as many of the other great men.

James Mills Bush (May, 1808-February 14, 1875) studied medicine first with Dr. Alben Goldsmith at Louisville, then, with Dr. B. W. Dudley, while taking the regular course at Transylvania University Medical College, from which he received his M. D. degree in 1833. In 1837, he was appointed Adjutant Professor in Anatomy, and, in 1844, full Professor of Anatomy in his alma mater, Dudley resigning the chair of Anatomy in his favor. In 1850, he

moved to Louisville and was appointed Professor of Surgical Anatomy and Operative Surgery in the Kentucky School of Medicine which had just been established, and he lived there for a time. Bush and Dudley formed a partnership in their practice which was most successful. Dr. Bush was particularly expert with the lithotrite, and he is said to have performed 210 litholapaxys with but four deaths. Bush had arranged with a Mrs. Bentley to lodge his patients and to aid him in their care. They frequently came from a considerable distance. He later was active in establishing St. Joseph's Hospital, at Lexington, Kentucky, which was the first hospital in Central Kentucky.

Charles Caldwell (May 14, 1772-July 9, 1853) was a native of North Carolina. After teaching school for some years he graduated in medicine from the University of Pennsylvania. His career as a student was stormy and marked
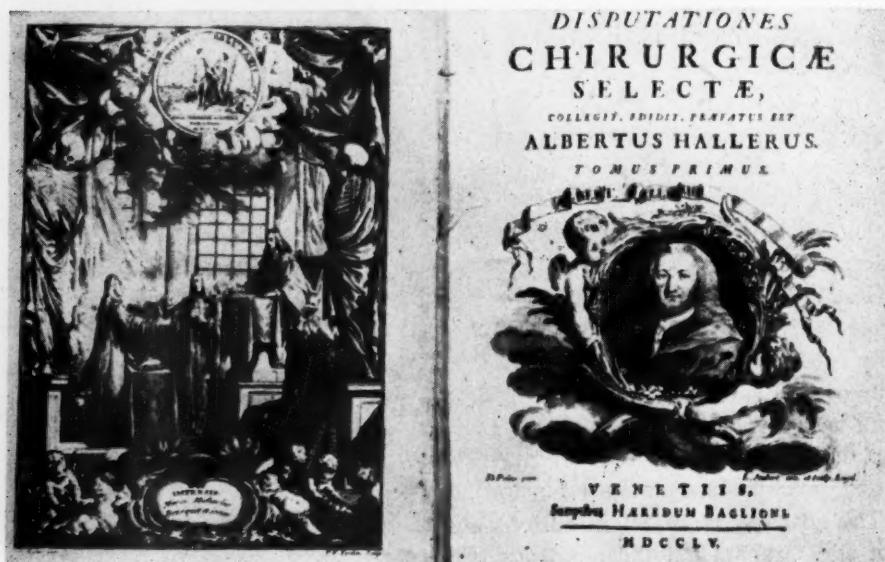

FIG. 15.—Albert Haller—Disputationes Chirurgicae Selectae. Published 1755.

by his aggressiveness and many quarrels with his associates. At first an ardent admirer of Benjamin Rush, he ended by quarrelling with him and daring to openly speak against his well known views on yellow fever. The young student wrote much for the newspapers and delighted in the notoriety he achieved. He embraced every opportunity to place himself in the limelight. In his autobiography he describes with magnificent conceit his services as surgeon with the troops who were sent to put down the Whiskey Insurrection. He seems not only from his own account, but from the statements of others, to have labored bravely in the yellow fever hospitals during the epidemic from 1793 around devastated Philadelphia until 1805. He sought in vain to get a professorship in the University of Pennsylvania. He organized classes for private teaching on several occasions but his efforts all ended in failure, and he was involved in one quarrel after another with his fellow physicians. He wrote many papers for medical journals. He at one time edited "The Portfolio" and

Delaplanes—"Repository of the Lives and Portraits of Distinguished American Characters." In 1818, he moved to Lexington as Professor of the Institutes of Medicine and Clinical Practice in the Medical Department of Transylvania University. It was impossible for him to keep out of medical politics and in a few years he was involved in quarrels with his colleagues. In 1837, he sought the removal of the Medical School of Transylvania from Lexington to Louisville.

This was opposed by Dudley, and other members of the faculty, and the trustees of Transylvania formally dismissed him from the faculty. He went at once to Louisville and enlisted the interest of the citizens, so that $20,000 was soon raised for the establishment of the Louisville Medical Institute. Caldwell was appointed Professor of the Institutes of Medicine, Medical Jurisprudence and Clinical Medicine. In 1846, the Louisville Medical Institute became a part of the University of Louisville. His writings and speeches both in Pennsylvania and Kentucky were most voluminous. While in Pennsylvania he edited Cullens Practice of Physic, and delivered many clinical lectures in Old Blockley Hospital in Philadelphia, and, in 1819, even wrote the Life and Campaigns of General Green. One of his most erudite articles is on Phrenology. He was a friend and physician of Henry Clay, who, in one of his speeches in the United States Senate, said of him : "A new philosophy has sprung up within a few years past called phrenology. There is, I believe, something in it, but not quite as much as its ardent followers proclaim. According to its doctrines, the leading passions, propensities, and characteristics of

FIG. 16.—Aur. Philip Theoph. Paracelsi— Opera Omnia. Published 1658.

every man are developed in his physical conformation, chiefly in the structure of his head. Gall and Spurzheim, its founders, or most eminent propagators, being dead, I regret that neither of them can examine the head of our illustrious Chief Magistrate (Andrew Jackson). But, if it could be surveyed by Dr. Caldwell, of Transylvania University, I am persuaded that he would find the organ of destructiveness prominently developed. Except an enormous fabric of executive power for himself, the President has built up nothing, constructed nothing, and will leave no enduring monument of his administration."

He continued teaching medicine and clinical practice until 1849, when he had another of his misunderstandings and quarrels and was dismissed from the

Medical College of Louisville. He continued to live in Louisville until his death July 9, 1853. The last four years of his life he spent in study and writing. He contributed many papers to Journals and Periodicals, and he also completed his autobiography. His works are voluminous and aggregate more than 10,000 pages. These are all on file in the Transylvania Library.

Dr. David W. Yandell in his Doctor's Address on the occasion of the Semi-Centennial Anniversary of the Medical Department of the University of Louisville, 1887, said: "The central figure of that group of noted teachers who founded the University was Charles Caldwell. He was a massive man in body and in mind. He was both tall and broad. His carriage was erect. His head was simply grand; his mouth was large; his eyes were bluish-gray. He had studied

Fig. 17.—Frederick Hoffmann—Opera Omnia Physico-Medica. Published 1790.

elocution. His gestures and his speech were studied also. His manners, usually cold, were always stately. He spoke in long, well-rounded periods, and in a great sonorous voice. He was learned in the languages, fond of study, and of abstemious habits. Besides all this, he was a man of affairs, and delighted in controversy. He taught the physiology of his day, which was then largely the physiology of the ancients, but he taught it in so impressive a manner that his classes received it as gospel and voted him its greatest expounder."

Daniel Drake was born at Plainfield, New Jersey, October 20, 1785, moved with his parents to Mason County, Kentucky, in 1788, and, in 1800, was the first medical student in Cincinnati. In 1805–06, he was a student at the University of Pennsylvania Medical College in Philadelphia, after which he practiced in Mays Lick, Mason County, Kentucky, and moved to Cincinnati in 1807 where, for a number of years, he enjoyed a large practice. In 1817, he

moved to Transylvania Medical School as Professor of Materia Medica and Medical Botany, but returned to Cincinnati, and, in 1818, founded the Medical College of Ohio. After a controversy in Cincinnati, he returned to Lexington in 1823 and stayed until 1827, being the Dean of the Faculty. He declined a chair at the University of Virginia in 1830, but he accepted one at the Jefferson Medical College, Philadelphia, the same year, and again came back to the Medical College of Ohio in 1830-32. He founded a new school as a department of Cincinnati College and taught in it 1835-1839, and he afterwards accepted a chair in the Louisville Medical Institute 1838–1849, and then went back to Cincinnati as a member of the faculty of the Medical College in 1849–50. In 1827 he was editor of the Western Medical and Physical Journal, but his

FIG. 18.—Theophilus Boneti—Sepulchretum. Published 1700.

chief work is his "Treatise on the Principal Diseases of the Interior Valley of America," published in 1850. He died in Cincinnati, November 5, 1852, age 67, literally worn out by his work.

Dr. David W. Yandell says: "As a lecturer Doctor Drake had few equals. He was never dull. His was an alert and masculine mind. His words are full of vitality. His manner was earnest and impressive. His eloquence was fervid." Soon after Dr. Yandell had entered the practice of medicine Drake had told him: "I have never seen a great and permanent practice the foundations of which were not laid in the hearts of the poor. Therefore, cultivate the poor. If you need another, though sordid reason, the poor of today are the rich of tomorrow, in this country. The poor will be the most grateful of all your patients. Lend a willing ear to all their calls."

Dr. S. D. Gross says of him: "He was a self-made man, he possessed genius of a superior order and successfully coped with his colleagues for the highest place in the school (Transylvania). Of all the medical teachers I have ever known, he was, all things considered, one of the most able, captivating and impressive. There was an earnestness, a fiery zeal about him in the lecture room which encircled him, as it were, with a halo of glory."

Dr. Ransohoff says: "It would be beyond reason on an occasion like this to touch upon every activity of so versatile a man as Drake, and one can only touch upon the chief of the many radiating ways travelled by the influence of this master mind. And of them, next to that of his written work, was that of the lecture room. Drake loved to teach, and because he loved it, did it well. During 35 years, he held nine professorships, in five different schools. A restlessness innate in his make-up and an habitual discontent with his professional environment made him an itinerant in medicine. The longest continuous professorship, ten years, he held in Louisville."

Dr. James Overton was appointed to the chair of Materia Medica and Medical Botany in 1809. When the faculty was reorganized in 1815, he was appointed to the chair of Theory and Practice. He moved from Lexington to Nashville, Tennessee, in 1818, where he practiced his profession for many years, dying at an advanced age. While in Nashville he became the physician and intimate friend of Andrew Jackson and was often entertained at the Hermitage.

John Esten Cooke was a native of Boston, his parents being from Virginia. He succeeded Daniel Drake as Professor of Theory and Practice at the Transylvania Medical College in 1824, and continued until 1837, when he moved to Louisville. He was greatly beloved by his patients and fellow physicians and Dr. Lunsford P. Yandell, Sr., wrote about him. "that Dr. Cooke was one of the few men who might have been trusted to write his own autobiography. He would have reviewed his career with a truthfulness, a modesty, a candor that would have exalted his character in the eyes of men. His works will be read by the curious for a long time to come, and will always be read with advantage by the earnest student." He was a great believer in medicine and his chief reliance was placed on calomel and quinine and his enormous doses of them created many arguments among his colleagues. A great many stories have been told about Dr. Cooke.

Dr. Lunsford P. Yandell, Sr., was called to the chair of Chemistry and Pharmacy in the Medical Department of Transylvania University, March 16, 1831. He occupied various chairs in the Medical School until he resigned in 1859 to accept a chair in the Medical School of Memphis, Tennessee. During the Civil War he devoted himself to hospital service. In 1862, he was licensed to preach by the Presbytery of Memphis, and, in 1864, was ordained pastor of the Dancyville Presbyterian Church. In 1867, he resigned his pastorate and returned to Louisville to resume the practice of medicine. While in Lexington he was for some years editor of the Transylvania Journal of Medicine, and in Louisville, he was editor for the Western Journal of Medicine and Surgery. He was the author of many medical papers and addresses. In 1872, he was elected President of the College of Physicians and Surgeons of Louisville, and

at the time of his death he was President of the State Medical Society of Kentucky. His death occurred February 4, 1878.

Charles Wilkins Short was another of the professors at Transylvania. He was born in Woodford County, Kentucky and was a most zealous and industrious botanist. He had an extensive herbarium and exchanged specimens of his with various botanists of the world. At his death his vast collection of botanical specimens to which he had devoted so great a portion of his life, was bequeathed to the Smithsonian Institute at Washington, but as there was no appropriate place there in which to display so large a collection, it was given to the Academy of Natural Sciences at Philadelphia. He was Dean of the Medical Faculty of Transylvania for about ten years.

FIG. 19.—William Fabricus—Opera. Published 1646.

FIG. 20.—Ambroise Pare—Les Oeuvres. Published 1607.

Ethelbert Ludlow Dudley was a nephew of the distinguished physician, Dr. B. W. Dudley, and was his private pupil and assisted him for many years. He graduated at the Medical Department of Transylvania University in 1842, and he was appointed Demonstrator of Anatomy in Transylvania. He afterwards served as professor of General and Pathological Anatomy and Physiology, and he was editor of the Transylvania Medical Journal and, in 1858, visited Europe for professional improvement, and he later taught Anatomy and Histology in the Kentucky School of Medicine in Louisville. When his uncle, Dr. B. W. Dudley, retired from Transylvania, he was appointed Professor of

Surgery in Transylvania, and after that he taught surgery in the Kentucky School of Medicine and gave clinical instruction in the Marine Hospital in Louisville. After that he resigned his position in Louisville and returned permanently to Lexington and resumed his practice there. At the outbreak of the Civil War he volunteered and organized a regiment for active service instead of taking the position of Medical Director which had been offered him. He was physician and surgeon to his men as well as their Commanding Officer, and while on an expedition in Southern Kentucky contracted typhoid fever and died February 20, 1862.

It is told by a member of his family that when he was a very young graduate of medicine he was assisting his uncle, Dr. B. W. Dudley, in an operation for stone in the bladder. Dr. Dudley was seized with a violent sick headache and became dizzy, being subject to these migraine headaches. He was unable to proceed so asked Dr. Ethelbert Dudley to go on with the operation. With much trepidation he did this successfully and the patient survived. This was his first lithotomy.

A great many of his papers and personal case notes were in the possession of his grandson, the late Dr. Scott Dudley Breckinridge, of Lexington, and were destroyed in a fire at his home several years before Doctor Breckenridge's death.

Dr. William H. Richardson was appointed professor of obstetrics, when the faculty was reorganized in 1815, and taught until the time of his death in 1844. Dr. Richardson was highly respected by his pupils as a practical teacher, notwithstanding the fact that he had not had the advantage of a college education. He was a man of great energy and of many admirable traits of character. His pupil, the late Dr. Lewis Rogers, in his address as President of the Kentucky State Medical Society, in 1873, speaks about him as follows:

"Few men ever had nobler traits of character. He was warm-hearted, brave, and a sincere friend. I knew him from my earliest boyhood, and have passed away many happy and instructive hours at his magnificent home in Fayette County. His hospitality was profuse and elegant. I listened to his public teachings as a professor with interest and care, because I knew he taught the truth as far as he possessed it. He was not scholarly nor graceful and was not fluent as a lecturer, but he was ardent and impressive, sufficiently learned in his special branch and had at his command a large stock of ripe experience. I honor his memory beyond most men I have known."

Dr. Robert Peter was born in England, January 21, 1805. His parents settled in Pennsylvania and he attended the Rensselaer Institute Scientific School at Troy, New York, where he lectured on the Natural Sciences, and he taught Chemistry and the Natural Sciences in several schools in Pennsylvania. In 1832 he came to Lexington, Kentucky, to deliver a course of lectures at the Eclectic Institute in Lexington, and, in 1833, he was elected to the Chair of Chemistry in Morrison College, Transylvania University. Besides teaching chemistry he studied medicine at Transylvania University, and received his diploma in 1834. In 1838, he was elected to the Chair of Chemistry and Pharmacy at Transylvania Medical Department. From 1847–1859 he was Dean

of the Faculty and Librarian as well. In 1839, he with Dr. James M. Bush made a trip to London and Paris for the purchase of books, apparatus, and other means of instruction for the Medical Department.

He wrote from London, August 11, 1839: "We have bought a great many fine books and a great deal of excellent apparatus and anatomical and other models. Transylvania will shine. No other institution in any part of the world will be able to compare with her in the means of instruction. In fact, I have seen none in Europe that is more completely prepared to teach modern medicine." He gave his attention to Chemistry, Geology, Mineralogy, Zoology and Botany. He was associated with Dr. Charles W. Short in the last named (Botany). He was the author of the first Geological survey of Kentucky, which was begun in 1864. He continued to teach and write and lecture and retained an activity of mind up to a very short time before his death which took place at Winton, eight miles from Lexington, at the age of 89, April 26, 1894.

The arrangement of the Medical Library is still as it was a century ago. The old classification is as follows:

A. *Practical Medicine,* including Pathology and Mineral Springs, *etc.*
B. *Anatomy and Surgery,* including Morbid Anatomy and Dentistry.
C. *Physiology,* including Medical Jurisprudence, Phrenology and Hygiene.
D. *Obstetrics,* including Diseases of Women and Children.
E. *Chemistry,* including Electricity, Magnetism.
F. *Materia Medica,* including Pharmacy, Medical Botany, and Dietetics.
G. *Natural History,* including Geology, Mineralogy, Botany, Zoology, Comparative Anatomy and Physics.
H. *Scientific Periodicals.*
I. *Periodical Medicine.*
K *Miscellanies,* including Physics (or Natural Philosophy), Voyages and Travels, Biography, Veterinary Medicine, Meteorology, Agriculture, Horticulture, Arts and Trades, Statistics and Works on General Literature.
L. *Encyclopedias,* including Transactions of Societies, the Works of the Old Fathers of Medicine and the Theses.

Practical Medicine:

AVICENNA (980–1036) called the "Prince of Physicians." His wonderful description of the origin of mountains fully entitles him to be called the "Father of Geology." His "Canon" is a huge, unwieldy storehouse of learning, in which the author attempts to codify the whole medical knowledge of his time and to square its facts with the systems of Galen and Aristotle. Written in clear and attractive style, this gigantic tome became the fountain-head of authority in the Middle Ages. Yet upon the whole, the influence of the "Canon" upon medieval medicine was bad in that it confirmed physicians in the pernicious idea that ratiocination is better than first-hand investigation.

BICHAT (1771–1802) earliest 19th century exponent of anatomy and scientific medicine in France; creator of descriptive anatomy.

BOERHAAVE (1668–1738) leading physician of his age; now remembered as a great teacher (Haller and Cullen were his pupils) and especially as a chemist.

BOTALLO (b. 1530) A pupil of Fallopius; taught that blood ought to be drawn in all diseases, even in those of a chronic character, and that it should be taken frequently and abundantly. This sanguinary doctrine gained many adherents, especially in Italy and Spain.

CORVISART (1755–1821) Napoleon's favorite physician, and the teacher of Dupuytren, Laennec and Cuvier, is now remembered chiefly through his revival of Auenbrugger's work on percussion, a translation of which he appended to the third edition of his "Essay on the Diseases and Organic Lesions of the Heart and the Great Vessels" (1818). As a clinical teacher and pathological anatomist Corvisart exercised an extensive influence. As a diagnostician he enjoyed the greatest reputation.

CULLEN (1710–1790) Instrumental in founding the medical school of Glasgow in 1744, and, during his long life, held the chairs of medicine and chemistry at both Glasgow and Edinburgh. He was one of the first to give clinical or infirmary lectures in Great Britain, and his lectures were the first ever given in the vernacular instead of Latin (1757). His "First Lines of the Practice of Physic" (1776–84) was for years authoritative on medical practice, even among the pioneers and "forty-niners" in the Far West.

HALLER (1708–77) the master physiologist of his time and one of the most imposing figures in all medical history. He was equally eminent as an anatomist, physiologist, and botanist. He wrote poems and historical novels, carried on perhaps the most gigantic correspondence in the history of science, and lectured and wrote on surgery but never performed an operation in his life. He made a superb medical and surgical and scientific bibliography.

HARVEY (1578–1657) the greatest name in 17th century medicine is that of William Harvey, who studied at Padua as a pupil of Fabricius, and whose work has exerted a more profound influence upon modern medicine than that of any other man save Vesalius. The importance of Harvey's work, then, is not so much the discovery of the circulation of the blood as its quantitative or mathematical demonstration. With this start, physiology became a dynamic science.

HIPPOCRATES (460–370 B. C.) gave to Greek medicine its scientific spirit and its ethical ideals. The eminence of Hippocrates is three-fold: he dissociated medicine from theurgy and philosophy, crystallized the loose knowledge of the Coan and Cnidian Schools into systematic science, and gave physicians the highest moral inspiration they have. To him medicine owes the art of clinical inspection and observation, and he is, above all, the exemplar of that flexible, critical, well-poised attitude of mind, ever on the lookout for sources of error, which is the very essence of the scientific spirit.

LOUIS (1787–1872) founder of medical, as distinguished from vital, statistics. Principal works are his researches on pthisis, his work on typhoid fever which gave the disease its present name, and by his statistical proof that blood-letting is of little value in pneumonia.

MORGAGNI (1682–1771) work constitutes true foundation of modern pathologic anatomy, made pathology a genuine branch of modern science.

PARACELSUS (1493–1541) His influence was far reaching, and his real services were great. Far in advance of his time, he discarded Galenism and taught physicians to accept chemical therapeutics: he was the first to write on miner's diseases, and the first to establish a correlation between cretinism and endemic goiter; almost the only aseptist between Mondeville and Lister, he taught that nature heals wounds, and not officious meddling; he introduced mineral baths, and was one of the first to analyze them; was great in respect of his own time; does not seem particularly great in relation to our time.

COOPER, ASTLEY (1768–1841) He was one of the pioneers in the surgery of the vascular system, in experimental surgery, and in the surgery of the ear.

COWPER, WILLIAM (1666–1709) In one of his published works (1702) he described a pair of glands which are to this day known as Cowper's glands. He had a considerable surgical practice, and his papers, published in the "Philosophical Transac-

tions," prove that his attainments in pathology and comparative anatomy were as noteworthy as his knowledge of human anatomy and practical surgery. In 1696 Cowper was elected a Fellow of the Royal Society. In 1697 Cowper published "The Anatomy of Humane Bodies" using the plates of Godfried Bidloo, originally used by the latter in 1685. Bidloo resented this crude piece of plagiarism and an exchange of polemic writings between him and Cowper followed.

The Library has the original edition of Cowper's work and one can readily see that the original Bidloo plate was used, the new title appearing on a shield which was posted over the old title.

CRUVEILHIER (1791–1873) His atlases of pathology (1842) are among the most splendidly illustrated books on the subject.

DUPUYTREN (1777–1835) The ablest and best trained French surgeon of his time; a shrewd diagnostician, a wonderful clinical teacher, and a good experimental physiologist and pathologist. He first described the condition known as Dupuytren's contracture.

FABRICIUS (1537–1619) The very eminent teacher of Harvey; a pupil and successor of Fallopius, who won deserved credit by his teachings regarding the valves of the veins, and his studies in the history of development and in comparative anatomy. How carefully he observed may be judged from the fact that he knew the cavity of the tympanum in the new-born was filled with mucus, a fact rediscovered in our day.

FALLOPIUS (1523–62) A loyal pupil of Vesalius, discovered and described the chorda tympani, the semicircular canals, the sphenoid sinus, the ovaries, the round ligaments, and named the vagina and placenta. He was also a versatile writer on surgery, syphilis, mineral waters and other subjects.

LARREY, BARON (1766–1842) The greatest French military surgeon of his time, and surgeon to Napoleon's army, and was the first to amputate at the hip joint, doing two successful cases in 1803.

RUSH (1754–1813) Ablest American clinician of his time. Gave careful accounts of diseases under his observation, such as cholera infantum, dengue, yellow fever.

The Transylvania Medical School Faculty is well represented in this section with the following:

Bartlett, Elisha	"The Fevers in the United States"
	"Philosophy of Medical Science"
Caldwell, Charles	"Medical and Physical Memoirs"
	"Essays on Malaria"
Cooke, John Esten	"Treatise on Pathology and Therapeutics"
	"Autumnal and Winter Epidemics"
Drake, Daniel	"Principal Diseases of the Interior Valley of North America"
Eberle, John	"Theory and Practice of Medicine"
Mitchell, Thomas D.	"Materia Medica and Therapeutics"

Anatomy and Surgery:

ALBINUS (1697–1700) One of the greatest anatomic illustrators of his time; held the chairs of anatomy and surgery and medicine at the University of Leyden. His own works are noted for their beauty and accuracy of illustration and for the elegant style of the accompanying text.

BEAUMONT (1785–1853) Was surgeon in the U. S. Army. In 1833 his "Experiments and Observations" was published. Beaumont's experiments on the effect of gastric juice upon different foods and the relative digestive values of the latter are the foundation of modern dietetic tables and scales. He was the true leader and pioneer of experimental physiology in our country.

BELL, CHARLES (1774–1843) leading British anatomist of the period is now more celebrated as a physiologist and neurologist. Accepted chair of surgery at Edinburgh in 1836.

BRIGHT (1789–1858) His "Reports of Medical Cases" (1827) containing his original description of essential nephritis, with its epoch-making distinction between cardiac and renal dropsy, at once established his reputation all over Europe. One of the greatest of modern pathologists and as an original delineator of disease, he ranks next to Laënnec.

MALPIGHI (1628–94) the greatest of the microscopists, the founder of histology, who was professor of anatomy at Bologna, Pisa, and Messina. Famed in biology for his works on the anatomy of the silkworm and the morphology of plants, he made an epoch in medicine by his investigations of the embryology of the chick and the histology and physiology of the glands and viscera. His work on the structure of the liver, spleen, and kidneys (1666) did much to advance the physiological knowledge of the viscera, and his name has been eponymically preserved in the Malpighian bodies of the kidney and spleen.

MONRO, ALEXANDER, Sr. (1697–1767) A professor of anatomy and surgery and eminent in both branches. He probably contributed more than any single individual to the success and the reputation of the medical school of Edinburgh.

PARÉ, AMBROÏSE (1510–90) A distinguished French surgeon who made himself the greatest surgeon of his time by his courage, ability, and common sense. Paré invented many new surgical instruments, made amputation what it is today by reintroducing the ligature, which had almost fallen into abeyance since the time of Celsus; was the first to popularize the use of truss in hernia; did away with the strolling surgeons' trick of castrating the patient in herniotomy; introduced massage, artificial eyes (of gold and silver), and staphyloplasty, and made the first exarticulation of the elbow joint (1536). He described fracture of the neck of the femur and strangury from hypertrophy of the prostate, and was the first to suggest syphilis as a cause of aneurysm. As Dr. Howard A. Kelly has pointed out, he was probably also the first to see flies as transmitters of infectious disease. In obstetrics, it was his description and use of podalic version that made the procedure viable and practicable, and he had the courage to induce artificial labor in case of uterine hemorrhage. In dentistry, he introduced reimplantation of the teeth, and his little treatise on medical jurisprudence (1575) was the first work of consequence on the subject prior to the "Methodus testificandi" of Codronchi (1597).

PETIT (1674–1750) Leading French surgeon of the early 18th century; was the inventor of the screw-tourniquet, gave the first account of softening of the bones and of the formation of clots in wounded arteries, and made improvements in amputations, and herniotomy. He was the first to open the mastoid process.

SCARPA (1747–1832) a great anatomist and surgeon; equally skilled as orthopedist and opthalmologist. Remembered for the triangle in the thigh which bears his name, his important treatises on hernia and eye diseases, and his shoe for club-foot.

SOMMERRING (1755–1830) wrote a monumental treatise on anatomy; made most important researches on the brain, the eye, the ear, nose and throat, and hernia, but is now best remembered for his remarkable accuracy in anatomic illustration and by his classification of the cranial nerves.

Physiology:

HUNTER, JOHN (1728–93) Eminent as a pathologic and comparative anatomist, and an investigator of the subject of inflammation and the blood. Masterpieces; "Natural History of Human Teeth" (1771): "Venereal Disease" (1786); "Treatise on Blood," Inflammation and Gun Shot Wounds" (1794).

HEWSON (1739–74) His "Experimental Inquiry into the Properties of the Blood" (1771) established the essential features of the coagulation of the blood.

PINEL (1745–1826) Stands high in medical history as the first to treat the insane in a humane manner. Real founder of the modern "open door" school of psychiatry.

Natural History:

This section should be particularly noted for its holdings. It is likely due to the fact that Rafinesque held the chair of Natural History and Botany as well as Librarian and helped increase this collection.

BONAPARTE, Charles Lucian; American Ornithology, 4 v.

BLUMENBACH Celebrated German naturalist: Founder of anthropology; professor of anatomy and medicine at Göttingen; first to teach natural history on basis of comparative anatomy; proposed the division of the human species into five races.

CUVIER Founder of science of comparative anatomy; celebrated French Naturalist.

GATESBY English naturalist. Library has his handsome elephant folio on "Natural History of Carolina, Florida, and the Bahama Islands."

DARWIN English Naturalist.

LAMARCK Celebrated French naturalist; one of the founders of the doctrine of biological evolution.

LINNE Celebrated Swedish botanist and naturalist; founder of the Linnean system.

MICHAUX, F. Andre and Andre—French naturalists.

LEEUWENHOEK Dutch microscopist and naturalist.

SWAINSON English naturalist.

Scientific Periodicals:

Quarterly Journal of Science and the Arts, 22 v. London, 1816–1827.
Tilloch's Philosophical Magazine, 65 v. London, 1798–1825.
Journal of the Franklin Institute, 21 v. Philadelphia, 1828–1838.
Silliman's Journal of Science and Arts, 49 v. New Haven, 1812–1845.

Medical Periodicals:

Medical and Philosophical Commentaries, 12 v. London, 1773–1778.
Medical and Physical Journal, 24 v. London, 1799–1810.
Medical Repository, 14 v. New York, 1804–1811.
North American Medical and Surgical Journal, 12 v. Phil. 1826–1831.
Western Medical and Physical Journal, 10 v. Cincinnati, 1827–1837.
Transylvania Journal of Medicine, 12 v. Lexington, 1828–1839.
Medico-Chirurgical Transactions, 22 v. Lexington, 1828–1839.
Philadelphia Journal of the Medical and Physical Sciences, 14 v. Phil. 1820–27.
American Journal of Medical Sciences, 26 v.: n. s. 10 v. Phil. 1827–1839. 1841–1845.
Medico-Chirurgical Review, 42 v. New York, 1823–1845.
Edinburgh Medical and Surgical Journal, 63 v. Edinburgh, 1805–45.
The Lancet, 35 v. London, 1823–1845.
London Medical Gazette, 20 v. London, 1827–1839.
Western Lancet, 16 v. Cincinnati, 1842–1853.

Fathers of Medicine:

DIOSORIDES' work is authoritative source on the materia medica of antiquity; first to write on medical botany as an applied science.

GALEN (131–201) founder of experimental medicine; was first and only experimental physiologist before Harvey.

RHAZES (860–932) his description of small pox, measles first authentic account in literature.

FRACASTORO (1484–1553) In his work "De Contagione" he states the modern theory of infection by micro-organisms.

HOFFMANN, FRIEDRICH (1660–1742) Born in Halle; was an eminent German physician, and years later was called to the newly founded university of Halle as professor of anatomy, surgery and practice, as well as of physics and chemistry. As a chemist he acquired lasting reputation by the numerous analyses of mineral waters, as well as by his investigations of the ethereal oils. In these studies he made the discovery of some special remedies, with which, like Stahl, he carried on a lucrative business. He was one of the most famous professors of his day, and, accordingly, brought his youthful university into a most flourishing condition. In 1709 he was called away to Berlin as ordinary physician to King Frederick I, but returned to Halle as professor. He was an extremely busy and fortunate practitioner, who even Boerhaave declared his own equal. He was an extraordinarily voluminous writer. An edition of his Latin works comprises 27 octavo volumes. His chief work was entitled "Medicine Rationalis Systematica" (1718–1740). He was the originator of the prescription which has come down to modern times "Hoffmann's anodyne."

In Sir Clifford Allbutt's view, Hoffmann was the greatest of the iatromechanists and the first to perceive that "pathology is an aspect of physiology." He left an original description of chlorosis (1730), and was one of the first to describe rubella (1740).

RUYSCH (1638–1731) advanced anatomy by the formation of anatomical collections, one of which was brought into Russia by Peter the Great at an expense of about $75,000. Also noted for the quaintly posed skeletons of his anatomical drawings.

WINSLOW (1669–1760) his anatomic work was authoritative text-book for nearly a century.

I have attempted to develop, in a small way, the origin and growth of Transylvania University, its Medical College, the faculty, and the Medical Library. As has been stated, this Library contains more than 10,000 valuable and ancient books, so it has been impossible in this short survey to give a fully detailed list, so I have presented a few of the most noteworthy authors, books and other publications. Many of these books are first editions. This library is housed in a brick and wooden building which is not fire and theft proof, and if we should have a fire all of them would probably be destroyed. Many of the books are in a good state of preservation, many need repairs and many need rebinding.

BIBLIOGRAPHY

Abell, Irvin: A Retrospect of Surgery in Kentucky: The Heritage of Kentucky Medicine. 1926.

Allen, W. B.: A History of Kentucky. Louisville, 1872.

Barkley, A. H.: Kentucky's Pioneer Lithotomists. Cincinnati, 1913.

Buck, A. H.: The Dawn of Modern Medicine. New Haven, 1920.

Caldwell, Charles: Autobiography. Philadelphia, 1855.

Caldwell, Charles: A Report made to the Legislature of Kentucky on the Medical Department of Transylvania University, February 15th, 1836. Lexington, 1836.

Choulant, Ludwig: History and Bibliography of Anatomic Illustration: Translated and Edited by Mortimer Frank. Chicago, 1920.

Drake, Daniel: Pioneer Life in Kentucky: Edited by Charles D. Drake. Cincinnati, 1870.

Garrison, F. H.: An Introduction to the History of Medicine. Philadelphia, 1914.

Graham, C. C.: Letters to Dr. Robert Peter, dated February 2, 1876 and February 12, 1876. (In manuscript)

Gross, S. D.: Autobiography, 2 v. Philadelphia, 1893.

Gross, S. D.: Then and Now: A Discourse Introductory to the Forty-third Course of Lectures in the Jefferson Medical College. Philadelphia, 1867.

Kentucky State Medical Society. Transactions, 1852. Louisville, 1853.

McCormack, J. N., ed.: Some of the Medical Pioneers of Kentucky. Bowling Green, 1917.

Packard, F. R.: History of Medicine in the United States, 2 v. New York, 1931.

Peter, Robert: Account Book on Trip to Europe, 1839. (In manuscript).

Peter, Robert: A Brief Sketch of the History of Lexington, Kentucky, and of Transylvania University. Lexington, 1854.

Peter, Robert: The History of the Medical Department of Transylvania University (Filson Club Publications No. 20). Louisville, 1905.

Peter, Robert: Transylvania University (Filson Club Publications No. 11). Louisville, 1896.

Pusey, W. A.: Giants of Medicine in Pioneer Kentucky. New York, 1938.

Stucky, J. A.: The Early History of Medicine West of the Alleghanies. In Clinical Medicine, v. 33, pp. 470–473.

Transylvania Journal of Medicine and the Associate Sciences. Edited by John Esten Cooke, Charles Wilkins Short, L. P. Yandell, and Robert Peter. 12 v. Lexington, 1828–39.

Transylvania Seminary. Records of the Proceedings of the Board of Trustees, 1783–1798. (In manuscript).

Transylvania University. Catalogs, 1821–1851.

Transylvania University. Medical Department. Minutes of the Faculty, 1819–1849. (In manuscript.)

Transylvania University. Records of the Proceedings of the Board of Trustees, 1799–1817; 1827–   . (In manuscript.)

NEWER CONCEPTS IN THE TREATMENT OF THE PARALYZED PATIENTS DUE TO WAR-TIME INJURIES OF THE SPINAL CORD*

OUTLINE OF PLAN AND STATISTICAL ANALYSIS

COL. DAVID HENRY POER, M.C., A.U.S.

ATLANTA, GA.

ONE OF THE INEVITABLE side-effects of war is the production of injuries which render many soldiers permanently handicapped and the unfortunate individual with paraplegia which was caused by damage to the spinal cord is unquestionably among the most pitiful. He is shadowed by the inevitable prospect of a fatal outcome in one to ten years which is usually brought about by the ravages of continuous infection of the urinary tract and its complications, and, in addition, by all the moral and physical retrogressive changes of severe chronic malnutrition. The method of treatment has usually consisted of those measures that would keep the patient in some degree of comfort during the few remaining months or years of this life. Fortunately, such a defeatist attitude has been prohibited by regulation during the war just ending.

During this conflict approximately 2,000 soldiers received spinal cord injuries as a result of the use of high velocity explosives and increasingly destructive ordnance products, and the Navy's figures probably total 500 additional cases (complete figures will not be tabulated for many months). The percentage may be low compared with the figures of previous wars (American Civil War, 0.25 per cent; Spanish-American War, 0.55 per cent; Balkan War, 0.6 per cent; World War I, 0.53 per cent), but when the total number of combatant troops are calculated the figure may rise above those indicated. This is due undoubtedly to the increased violence and damage of destructive forces used in this conflict.

The mortality rate shows a marked decrease from an all-time high in the Balkan Wars of 95 per cent (average other wars, 50 to 60 per cent) to approximately 20 per cent in this war. This remarkably low figure is the most commendable result of the organization and activities of the neurologic surgeons who sent their best trained specialists to the most forward echelons, at which point definite procedures were carried out. However, this lowering of the battlefield mortality produced a marked increase in the number of patients to be cared for in the General Hospitals in the United States, which at the present time totals 1,300 paraplegics for the Army alone. Approximately one-third of these will be discharged to their homes in the next few months, leaving a group of 800 or 900 to be cared for in veterans' facilities.

It is our purpose at this time to point out ways and means by which these individuals can be successfully treated and restored to the community capable

---

of self-support and some type of ambulation by which they can move themselves independently from one place to another. In such a scheme the generous pension granted by the government should serve only as a form of health insurance not obtainable elsewhere. Our plan is a joint project representing the value and results of specialization to its finest degree and by these activities the patient has reaped the highly desirable benefits.

THE PROBLEM

Confronted with a sizable group of what were so recently healthy and happy American youths who now had become paralyzed to some degree in the lower extremities and a few in the upper extremity as well, who were unable to control normal urine and bowel function, and who were faced with the formerly inevitable fatal complications of urinary tract infection of some intermediary condition no less serious, we stopped to survey the problem. Certainly a more dismal and discouraging problem was seldom presented before any group of physicians.

If our desiradetum was considered to be the restoration of that happy, healthy American youth to the ability to achieve financial and economic independence, to use his remaining muscle power with the aid of mechanical means to restore independence of movement, and to develop an adequate control over bowel and bladder function, then a certain degree of happiness and good health based on readjustment to such a tragic condition would become easier to obtain. Surveying this picture as a whole, we divided the treatment of an individual with injury to the spinal cord into three phases from the standpoint of medical installations in the military services and to a large degree the same divisions could be applied to civilian life:

I. *Initial and Early Treatment Phase.*—This begins with the treatment on the battlefield after wounding, transportation to the rear, and the first definitive treatment rendered in the Evacuation Hospital. It would cover the period of waiting in a numbered General Hospital until evacuated back to the United States.

II. *Corrective Treatment Phase.*—Upon arrival at a General Hospital in this country, malnutrition, decubitus ulcers, urinary infection and depression had usually developed and the second phase covers the correction of these conditions. In addition to these corrective measures any necessary neurologic surgery operations were performed for the removal of foreign bodies from the region of the injury and for the relief of pain, troublesome reflexes and spasticity. Attempts were made immediately to put the patient in a wheel chair soon after arrival as the first step to independent ambulation. Any associated injuries were dealt with, including closure of colostomies, removal of foreign bodies and completion of treatment of fractures. A well-planned educational, recreational and prevocational training program completed a very full day's activities throughout this period.

III. *Ambulation or Economic Security Phase.*—Upon completion of the procedures enumerated in Phase II, the more serious aspects of adjustment to

future life were now dealt with. To assist with ambulation some reconstructive orthopedic procedures were needed to provide stabilization of joints and return of motion. A set of exercises to provide strong trunk and upper extremity muscles were carried out vigorously and regularly. Special training and instruction in the use of braces, crutches, traction and special walking and sliding devices to teach the individual to sit, stand, fall, drive an automobile and handle himself in the toilet and bathroom were given. Instruction in a wide range of jobs, positions, business opportunities, technical trades, professional and subprofessional activities were insisted upon to insure the earning of an income sufficient for the needs of the individual and his family.

THE PLAN

In an Army General Hospital our chief part in achievement of such results for these patients has been the professional care indicated in the second and third phases. This report applies particularly to those procedures carried out in Phase II, because the end-results are near completion while the measures described in Phase III are still in the process of being carried out.

Any such program must have its single director in whom complete responsibility is vested because of the overlapping of the many special fields of professional interest involved. One might suggest the general practitioner who always has the entire patient as his chief field of interest, but the need for specialists has done away with those prospects. According to regulations these patients are sent to a Neurologic Surgery Center and while undoubtedly this specialist should play the leading part in this program, he is immediately confronted with many problems outside this field. The urologist has the most active part in the treatment during the early stages because of the constant care needed to make any type of urinary drainage operate properly. The internist has his part in the correction of nutritional and vitamin deficiencies; the surgeon, or plastic surgeon, has the decubitus ulcers and other surgical conditions to deal with; and the orthopedist treats the fractures and supervises the mechanical means of walking. We believe one condition to be absolutely essential in assigning a director for this program, and that is that the doctor must have a sincere humanitarian as well as professional interest in these patients to the extent that he will leave nothing unturned to achieve the results desired. Each hospital has had to make this selection on the basis of the qualifications of its staff members, but once put in charge the Director must have the entire responsibility for seeing that all specialists involved carry out their part without delay. In addition to the professional advantages which follow this fixed rule, a tremendous boost to the morale of each patient results because of the strong doctor-patient relationship that it fosters. Knowing that one instead of many doctors is in charge of his case, and that this doctor will call on all other specialists freely, and that he will also assist in the solution of their many personal problems, has provided the springboard from which these mentally and physically ill patients can begin their long trek back to a normal existence.

CONCLUSIONS

A plan used for the treatment of patients having sustained injuries of the spinal cord in war-time is presented and the details discussed. This covers the second and part of the third phase of the restoration of these individuals to a life of independent ambulation, an adequate control of bladder and rectal function, freedom of pain, relief of spasticity and troublesome reflexes, and an education or training adequate to make the individual self-supporting. This plan has been in use for 15 months, and the results are gratifying. Solution of specific problems in the various specialty fields will be discussed by each department.

STATISTICAL ANALYSIS

During the past 15 months 77 patients with injuries of the spinal cord have been received for treatment at the Newton D. Baker General Hospital. There are at the present time 250 patients in hospitals of the Fifth Service Command, and it is estimated that there are 1,300 in the General Hospital system in the United States. While the statistical compilations for the war recently ended will not be completed for many months, this number added to the fatal cases represents a percentage quite similar to that of other wars (World War, 0.53 per cent; American Civil War, 0.25 per cent; Spanish-American War, 0.55 per cent, and Balkan War, 0.6 per cent).

Etiology: Damage to the spinal cord in these individuals was produced on the battlefields in the European and the Pacific Areas for the most part (90 per cent) by high velocity bullets (17), shell fragments (50), and mine explosions (two). Considering the tremendous violence and destructive force of modern instruments of war, no part of the body could hope to escape injury, and the cord with its bony protection is no exception. Motorization of the vehicles of war has contributed its share of serious back injuries and includes the truck, jeep, airplane and command car in this series (one each). Two soldiers fell considerable distances and one dived into shallow water.

Associated Injuries: Over half of these patients (45—58.4 per cent) sustained serious injuries to other parts of the body at the same time, demonstrating more evidence of frightful effects of weapons used today. These included bullet and fragment wounds of the soft-parts, fractures of long bones, and injuries to the head, chest and abdominal organs.

Level and Degree of Injury: The cervical region was injured in one-fifth of the cases (15—19.7 per cent), and cauda equina of lumbar (18—23.6 per cent) and sacral (5—6.5 per cent) areas in 30 per cent. The remaining 39 (50.5 per cent) were injured in the region of the dorsal spine. Complete transsection of the cord was produced in 29 patients (37.6 per cent) and incomplete or partial in 44 patients (62.3 per cent). Neurologic survey has revealed some more or less bizarre findings in certain cases which has made the final decision as to the degree of the lesion problematic.

Age: Considering the usual idea of youth, the average age (25.4 years) seems high. One man of 40, and a boy of 19 are included in this group.

Marital Status: Twenty-two patients were married (28.5 per cent), and nine of these had children.

Education and Work: Thirty-five patients had received high school education, 16 grade school, and five were college students. Fifty-two (66 per cent) were laborers and white collar occupations of the others included musicians, clerks, accountants, and salesmen. Five were officers in company grade. A major general in another hospital was injured in a plane crash.

Nutritional Status on Admission: A high percentage of patients received in this country (74 per cent) had developed a serious degree of emaciation, with an average weight-loss of 42.5 pounds per person. Since these patients always received a high priority for food rations in all installations, this condition must be ascribed to other causes, and chief among these is the severe depression and loss of appetite that follows such a tragic event. Moderate to severe secondary anemia existed in this same group as shown in average red cell counts, hemoglobin and hematocrit. Determinations by the micro-Kjeldahl method showed 36 patients (46.8 per cent) to be in negative nitrogen balance with reversal of the albumen-globulin serum ratio, and with excess calcium excretion in the urine.

Decubitus Ulcers: Forty-four patients (57.1 per cent) had decubitus ulcers on arrival, due undoubtedly to the inability to render adequate nursing care at all times and places. The exigencies of travel in war-time, with its inevitable delays and inconveniences, have remained beyond control. Since it is known that a decubitus ulcer will develop in a matter of hours in a nonparalyzed individual, such occurrence in this group will always remain high. The ulcers were multiple in 31 patients, averaging from two to 11 per individual. Patients transported by air were invariably in better condition as regards nutrition and decubitus ulcers than those moved by other means of travel.

In this large group of patients the factor of loss of proteins in the secretions from the ulcers presented an additional nutrition problem. Using the methods of Cotui and Mulholland, the protein loss was found to be:

50 Gm. plus — 2 cases
40 Gm. plus — 4 cases
30 Gm. plus — 4 cases
20 Gm. plus — 8 cases
10 Gm. plus — 9 cases
5 Gm. plus — 8 cases
Less than 5 Gm. — 2 cases

Bladder Status: Since regulations required it, a suprapubic cystotomy had been done before evacuation to this country, in all patients not voiding except one (33 voiding, 43 cystotomies). Urinary infection had developed in all patients except three, and the causative organism was usually one or more of the gram-negative group (*Aerobacter aerogenes, B. proteus, Esch. coli,*

Staphylococcus aureus and *albus, B. coli* (intermediate), *B. pyocyaneous,* pericolon, *gamma Streptococcus*).

Neurologic Status: Most of the findings are presented in a subsequent report, but as a factor to be dealt with immediately upon admission, 13 patients (1.6 per cent) had severe pain, 10 (1.2 per cent) had troublesome reflexes referred to also as spinal or mass reflexes, and 12 (1.5 per cent) had a marked degree of spasticity. Forty-four patients (57.1 per cent) had had primary laminectomy performed before evacuation.

Mental Status: While some degree of depression was to be expected when patients having had such a catastrophic injury first return to their home land and are visited by their families, yet only one psychosis was observed.

Ambulation on Admission: Since all patients were received by litter, and unless serious complications were present, everyone was expected to be placed in a wheelchair within a month after admission.

Mortality: There has been one death in this series (1.3 per cent). This remarkably low figure stands as fine tribute to the personnel who rendered the professional and nursing care to these unfortunate individuals. The cause of death in this instance was the complications of ascending pyelonephritis and pulmonary abscess.

SUMMARY

The essential vital statistics of a series of patients having injuries to the spinal cord are presented. The treatment of these patients will be presented in subsequent reports by the special sections involved.

NEWER CONCEPTS IN THE TREATMENT OF THE PARALYZED PATIENT DUE TO WAR-TIME INJURIES OF THE SPINE

II—NEUROSURGICAL COMPLICATIONS*

LT. COL. CHARLES W. ELKINS, M.C., A.U.S.,

AND

LT. COL. WALTER R. WEGNER, M.C., A.U.S.

FROM NEWTON D. BAKER GENERAL HOSPITAL, MARTINSBURG, WEST VIRGINIA.

DURING THE PAST YEAR AND A HALF we have had the opportunity of observing a series of 77 cases with war injuries of the spinal cord resulting in either complete or partial paralysis of one or more extremities and varying degrees of bladder and bowel dysfunction. On the basis of our experience, the conclusions are drawn that the most frequent neurosurgical complications in this type of patient are retained foreign bodies in close proximity to the spinal cord or peripheral nerve roots, intractable pain and uncontrolled spinal reflexes.

The interest of the Army Medical Corps has been aroused in these problems and much has been accomplished toward clarification of thinking and unification of treatment. Much remains to be accomplished and important contributions are forthcoming. The purpose of this paper is to present conclusions drawn from our experiences.

The occurrence of retained foreign bodies in, or close to the spinal canal or nerve roots, in our series was frequent, occurring in 12 cases. Indications for removal were grouped into four categories, the most frequent of which was the presence of intractable pain. The next most frequent indication was the presence of a foreign body either in, or in close approximation to, the cauda equina. The location was considered an indication for removal even in the absence of pain in hopes that removal of scar tissue would permit some recovery of function or to prevent the development of increasing chronic adhesive arachnoiditis with pain or decreased function at some future date. The presence of an intraspinal foreign body in any location was considered to be an indication for removal either in complete or partial transections. By this it was hoped that the development of sequelae due to continued scar tissue formation could be prevented. In addition, the difficulty in clinically recognizing a complete from an incomplete transection is well known and it was hoped that some clinical improvement might take place following removal of an intraspinal foreign body. A persistent draining sinus was the final indication for foreign body removal in our series and as this indication is fundamental, nothing further need be said on this matter.

The results insofar as relief of pain was concerned were on the whole satisfactory. Of the five cases in which the only indication for removal of the foreign body was the presence of pain, it is significant to note that no

further procedure for relief of pain has been necessary. Complete relief, however, did not occur in all cases. Evaluation of results in those cases with foreign bodies in, or in close approximation to, the cauda equina has been difficult. Of the three cases falling in this category, none have actually improved in function but, on the other hand, there has been no decrease in existing function nor has any case developed pain. We believe that only because of the limitations in numbers of our series have we failed to obtain some improvement in function following the removal of a foreign body and lysis of the cauda equina. We cannot properly evaluate results in those cases in which the only indication for removal of a foreign body was its intraspinal position, except to state that in neither of the two cases in this category has improvement of function occurred, although in neither case has further unpleasant sequelae developed. In two cases draining sinuses promptly healed following removal of a foreign body.

It was early recognized in our experience that the problem of pain in the paralyzed patient was a difficult one. Because of generalized debility, the threshold to pain in many cases was unquestionably low. In certain cases however, persistent pain was present and contributed largely to the patient's debility. Request that the patient describe his type of pain led to a wide variety of responses. These differed from a simple radicular or root-type to generalized burning, aching or pulling sensation usually in an extremity but occasionally in the bladder or rectum. Recognition of the etiologic agent such as a foreign body in close approximation to the central or peripheral nervous system was sometimes fairly simple but in other cases the causative factor seemed somewhat more obscure. It was recognized that following injury to the spinal cord, scar tissue was inevitable and that in certain cases lysis of this scar tissue would result in relief of pain. By and large, however, this type of procedure, to be effective must be extensive and it was evident to us that these debilitated cases would not easily tolerate any extensive procedures and as the relief of pain in certain cases was almost a life-saving procedure, we chose spinothalamic cordotomy as the procedure of choice provided that the more simple and well-known procedures proved unsatisfactory. We avoided alcohol injection of the spinal subarachnoid space because of the danger of upsetting a bladder physiology which usually was already precarious.

The results of our program for the relief of pain have been eminently satisfactory. The greatest single factor has been improvement in general nutrition amongst this group. Unquestionably, the tolerance to pain rises with decrease in debility. Three cases of spinothalamic cordotomy were performed, and in two cases the relief of pain has been dramatic. Both rapidly gained weight and are now ambulatory with braces. The third case continues to complain periodically but no longer requires narcotics. In evaluating results of the entire pain program, the amount of narcotics necessary on the ward may be considered to be the criteria of success or failure. Narcotics and the fear of drug addiction in this group of patients no longer constitute an important problem.

517

The third major neurosurgical complication existing in a large percentage of paralyzed patients is uncontrolled spinal reflexes. The variety of these reflexes, from simple flexion to the widespread overflow of the mass reflex lead to much confusion, and the tendency has been to lump them all together under the single item "mass reflex." However, as long as specific variations are hidden by such a vague generalization, thinking will tend to be obscured and progress in determining why certain reflexes occur in one patient and not in another will be delayed.

The classical descriptions of reflex activity in spinal injuries were published by Sherrington,[1] Walshe,[2] and Head and Riddoch.[3] Their basic conclusions have not been disproven, although they are questioned in some quarters because of the difficulty in explaining varied reflex findings by reference to classical concepts. Six rather definite spastic types are recognizable.

TABLE I

SPASTIC REFLEXES

Name	Features of Reflex	Type of Stimulus	Reflexogenic Area	Purpose
1. Flexion (simple)	Flexion at hip, knee, and dorsiflexion at ankle and toes. May be contraction of abdominal muscles on same side	Normally painful; cutaneous	Plantar surface of foot especially, but stimulus anywhere else on thigh or leg may produce it	Removal of the part from cause of discomfort
2. Extension	Extension of thigh, knee, and plantar flexion at ankle. Hamstrings contracted. Adductors of thigh usually contracted	(a) Muscle stretch or (b) Skin stroke	(a) Stretch of any extensor muscle, or (b) Stroking of skin, especially inside of thigh or perineum	(a) To maintain position (b) Sexual reflex, producing posture of copulation
3. Crossed extension	When one limb engages in a flexion reflex the opposite limb extends	Same as for flexion reflex. (1)	Same as (1)	To give support as ipsilateral limb is withdrawn from stimulus
4. Extensor thrust	Extension as in (2)	Pressure	Pressure against toe pads or sole with knee in slight flexion	To maintain posture
5. Reflex stepping	Production of extensor thrust on one side produces flexion of opposite leg. These movements may then continue alternately	Stretch of gastrocnemius when knee is flexed	Proprioceptors of gastrocnemius	Maintenance of posture in progression
6. Mass reflex	Flexion of ipsilateral limb. There may be flexion or extension of contralateral limb. Contraction of bladder, sweating. (Flexion of limb coupled with one or more of the purposeless manifestations will suffice)	Painful or innocuous skin stimulation, or stimulation of muscles and tendons (proprioception)	Skin of thigh and lower abdomen, perineum or deep structures of lower extremity (proprioceptive)	Partly to remove leg from threatening stimulus, but remainder of reaction is without purpose in primates

These are simple flexion, extension, crossed extension, extensor thrust, reflex stepping and mass reflex. Table I is presented to describe the features of the reflexes associated with transverse lesions of the spinal cord. It is meant as a working classification and certain physiologists may question its exactness, yet, if it serves to bring some order out of chaos, it will have served its purpose.

All of these reflex activities have been observed in our patients except the extensor thrust. Attempts have been made to find the reasons for variation in reflex response from patient to patient and they have not been successful. Except for the uniform flaccidity of cauda equina lesions, one can find no reflex characteristics which are definitely typical of the level or degree of severity of the cord lesion. Of two patients having lesions of the same age, at the same level, and of approximately equal severity, one may have spastic reflexes while the other is flaccid; or if both are spastic, one may be in flexion and the other in extension. Thus, there is a definite need for critical reëxamination of accepted concepts and especially for correlation of detailed pathologic findings in the spinal cord with observed clinical phenomena whenever the opportunity arises.

One of the conclusions drawn by the above mentioned authors, and confirmed in our experience, is that extensor reflexes are generally observed in anatomically incomplete lesions of the spinal cord. Except for an occasional variation, the hip, knee and ankle joints are strongly extended and resist passive flexion. Accompanying clonus is frequent. This fact should make one cautious in treating extensor spasms by a destructive operation, such as anterior rhizotomy,[5] which would permanently preclude the possibility of spontaneous recovery of function.

In trying to fit the clinical findings of paraplegics into a neurologic pattern one must not lose sight of the fact that they may have multiple or widespread lesions rather than a single restricted lesion at the point of injury. This is true for closed injuries of the spine as well as for gunshot wounds. Discontinuous areas of hematomyelia may occur extending from the medulla to the conus medullaris. That less extensive hematomyelia is not uncommon in paraplegic soldiers, is evidenced by the findings of isolated muscle atrophy and other neurologic changes which cannot be explained on the basis of a single lesion at a given level. This helps to confuse the reflex pattern.

It is well not to regard a given reflex state as necessarily fixed, even when there are strong flexor or extensor spasms in obviously severe lesions. Some patients will show a gradual reduction in this uncontrolled activity until finally their extremities are almost, if not quite, flaccid. Sherrington took note of this phenomenon and ascribed it to "isolation dystrophy" in the distal segment of the cord. We are unaware of any adequate pathologic study of this condition and suspect it to be a progressive effect of initial widespread trauma. That the cases observed by Sherrington's followers in World War I may not have been as free of sepsis nor as adequately nourished as similar patients are today may also have been a factor in causing the reflex activity to subside, for it is well known that toxemia may depress reflex activity; but that reasoning can hardly be applied to the cases seen today. Whatever the cause for the subsidence of spastic responses in the legs, whenever it occurs it is a great boon to patient and doctor.

As this remark indicates, our interest in the reflex activity of the traumatized spinal cord is not purely academic—these reflexes may present thera-

peutic problems, both in partial and complete lesions. In a small but trouble-some minority there will be flexor and extensor spasms of such strength as to greatly hinder or prevent ambulation—which is the primary goal of all paraplegics.

Generally speaking, it seems best to follow a conservative course in treating these spastic conditions because of the hope of spontaneous remission. This has been noted in total transections as well as in partial lesions. The treat-ment during this period should consist of splinting, physiotherapy, and any other simple method that particular circumstances indicate. Unfortunately, skin traction can seldom be employed because of the danger of pressure sores when such traction is used on partially or completely anesthetic skin. In one severe case with an incomplete lesion and beginning contractures we used Kirschner wire traction, and although it served the purpose very well, the frequent spastic jerking of the leg caused considerable pain at the site of the wire. With flexion reflexes one must guard against contractures at the hip as well as at the knee. With this in mind, it has been very helpful to have the patient lie on his abdomen a part of each day, with legs held flat by a folded sheet tied beneath the bed.

We have had some experience with curare, having used Squibb's "into-costrin" in six cases. It was given intramuscularly in doses starting at 1.0 mg. per kilo of body weight and increasing gradually to almost 3.0 mg. per kilo. The results were not striking and the only conclusion to be reached from our experience is that the brief and moderate improvement in spasticity produced by the curare is hardly useful except as an adjunct to other therapy, such as splinting, traction and passive exercise. We are still using it for this purpose and believe it has a definite place in the therapy of these patients.

The proper dose of curare must be determined individually for each patient. Unfortunately, the larger doses which produce the greatest relaxation of the extremities also produce so much drowsiness, weakness and double vision that the patient is unable to take an active part in his therapy program for the remainder of the day. It, therefore, seems better to use only moderate doses and to be content with less relaxation while retaining the continuous participation of the patient in his physical training. Only when moderate doses are used does there seem to be any relaxation of the spasticity without interference with the remaining voluntary motor activity, as some authors have described.[4] As there is a small carry-over of the curare effect for several days, single injections have been given at two-day intervals.

When time and conservative measures do not bring about sufficient relaxa-tion of flexor or extensor reflexes to permit ambulation, more radical therapy can be considered. When strong extensor reflexes are present there is usually such marked adductor spasm that one leg crosses over the other. This, of course, prevents walking, whether with braces and crutches or by voluntary power. In those patients with some voluntary motor function present in the lower extremities, relief of the adductor spasm often makes them ambulatory without the use of braces. Furthermore, as extensor spasms commonly

begin with contraction of the adductors, denervating these muscles may radically change the reflex picture and result in less spastic extremities. This desirable result can easily be obtained by dividing the anterior and posterior branches of the obturator nerve, thus, paralyzing the principal adductor muscles. Mere neurectomy should not be considered sufficient, however. During the months of adductor contraction, fibrotic changes have probably occurred not only in the muscles but around the hip joints as well. It is strongly recommended, therefore, that adduction splints be applied immediately after the operation and that their use at night be continued for some months. In those patients in whom it seems desirable to hasten spontaneous improvement by a temporary paralysis of the adductors, the obturator nerves can be crushed in a clamp, but then it must be expected that the muscles will function strongly again in a few months. We have relieved adductor spasms in two cases by these procedures and in both cases the patient was able to stand erect. In an earlier case, an incapacitating clonus practically disappeared over a period of several months of ambulation.

In patients who have severe flexor or extensor spasms with what appears to be a complete cord lesion, and this fact should usually be verified by a laminectomy—relief can be obtained by anterior rhizotomy. This procedure will not only produce flaccid legs, but will also stop much of the hyperactive bladder activity which is so troublesome when spastic paraplegics move about.

Anterior rhizotomy of the appropriate nerve roots, as described by Munro,[5] at times becomes the procedure of choice in patients with spastic contractures and uncontrolled spinal reflexes. We have employed this procedure in three cases successfully. In one case it was a life-saving procedure. Two of our cases are now ambulatory with braces. The third case may require tenotomies for the release of fixed contractures due to fibrosis around one knee. We are aware that selective spinal subarachnoid injections of alcohol have been advocated to control the less severe cases with spastic reflexes. Having had no experience in this procedure, we can offer no constructive criticism.

SUMMARY

Our experiences in the treatment of a series of spinal cord injuries have been interesting and illuminating. We have drawn certain conclusions, as presented above, but we recognize that the challenge has presented itself for further advances in a field which, a few short months ago and with few exceptions, was considered a hopeless proposition.

Lt. Col. Charles W. Elkins
Newton D. Baker General Hospital
Martinsburg, West Virginia

REFERENCES

[1] Sherrington, C. S.: The Integrative Action of the Nervous System. London: Constable, 1906.

[2] Walshe, F. M. R.: The Physiological Significance of the Reflex Phenomena in Spastic Paralysis of the Lower Limbs.   Brain, **37**, 269, 1914–15.

[3] Head, H., and Riddoch, G.: The Automatic Bladder: Excessive Sweating and Some Other Reflex Conditions, in Gross Injuries of the Spinal Cord.   Brain, **40**, 149, 1917.

[4] Bremer, F.: The Tonus and Contracture of Skeletal Muscles.   Arch. Surgery, **18**, 1463, April, 1929.

[5] Munro, Donald: Personal communication.

Surgery
. 1946

Spastic

Some
1917.
y, 18,

METHODS OF CLOSURE OF DECUBITUS ULCERS IN THE PARALYZED PATIENT*

CAPT. DONALD E. BARKER, M.C., A.U.S.,
LT. COL. CHARLES W. ELKINS, M.C., A.U.S.,

AND

COL. DAVID HENRY POER, M.C., A.U.S.

ARMY OF THE UNITED STATES

FROM THE NEWTON D. BAKER GENERAL HOSPITAL, MARTINSBURG, WEST VIRGINIA.

DURING THE PAST 12 MONTHS, it has been the authors' privilege to study a group of 80 cases of paraplegia due to war injuries of the spine. One of the most difficult of the many problems presented by this group of patients was the care of decubital ulcers which were present in a high percentage of the group. In consideration of the problem, a review of the information available in regard to decubital ulcers was carried out.

The factors responsible for the healing process of a decubital ulcer are the relief of pressure from the involved area, control of extraneous moisture,[1] a positive nitrogen balance,[2] and adequate vitamin intake.[3, 4] If these variables are considered and appropriate measures taken to correct deficiencies, it is recognized that healing will take place over a long period of time but at the expense of a considerable amount of nursing care to a slowly granulating and epithelizing surface. It is believed, however, that the presence of a large healing ulcer may, in itself, contribute to the patient's general debility and thus may be a factor in the slowness of healing. Mulholland, Co Tui, *et al.*,[2] studied the nitrogen balance in 35 cases with decubital ulcers, and concluded that the ulcers began to heal only when the blood serum protein began to rise and the nitrogen balance changed from negative to positive. They measured the protein output of one ulcer over a 24-hour period and found that during that period the patient lost 5.56 Gm. of protein from the ulcer. We, likewise, measured the protein output of decubital ulcers by collecting the débris and secretions for 24 hours on a nitrogen-free cellulose pad and then determining the nitrogen content by the Kjeldahl method. In one of our patients, with five ulcers of varying sizes, the 24-hour protein loss from these ulcers was 50 Gm. Thus, it may be seen that there is an appreciable loss of protein from decubital ulcers.

Because of these facts, we determined to attempt surgical closure of decubital ulcers. As a basis of experience, a search of the literature revealed that Lamon and Alexander[5] had reported one case of decubital ulcer treated by excision and closure. Furthermore, we became acquainted with the successful work of Major W. B. Scoville, at Cushing General Hospital, utilizing a method of secondary closure of large ulcers.[6] Foman, in 1939, states that small decubital ulcers could be excised and closed after becoming surgically clean. He also

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

stated that larger ulcers should be closed by skin grafting but no references were given and no cases cited in which this method was employed.[7]

In our series are included 70 cases of decubital ulcers which have been surgically closed by one of three methods. Twenty-four cases in this series were supervised by Captain Barker, at Nichols General Hospital, Louisville, Ky., and Ashford General Hospital, White Sulphur Springs, W. Va. The staffs of both hospitals gave unlimited coöperation. Excision and suture was employed in small ulcers, rotation flaps were utilized in large ulcers over the trochanters, and split-thickness skin grafts employed on large ulcers over the sacrum.

PREOPERATIVE MANAGEMENT

The preoperative management of a patient with a decubital ulcer consists of attempts to remove the patient from a debilitated state by means of adequate protein, vitamin and caloric intake. The preoperative care of a decubital ulcer consisted of attempts to acquire a clean granulating base. No attempt has
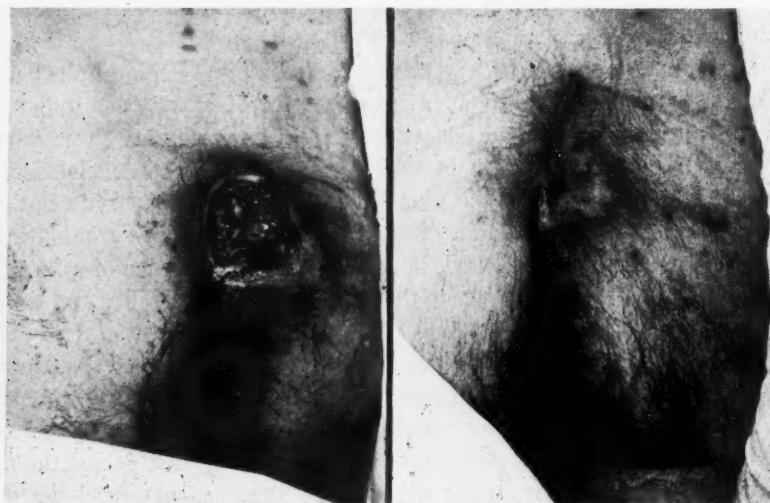

FIG. 1-A   FIG. 1-B
FIG. 1.—(A) Preoperative small sacral ulcer.
FIG. 1.—(B) Nine months postoperative.

been made to make an ulcerated area bacteria free. Various preparations were used to apply locally on the ulcer, as seemed indicated by the amount of slough and degree of reaction around the affected area.

OPERATIVE MANAGEMENT

In the main, we were confronted by three different types of ulcers. The small ulcers over the sacrum and trochanters were closed secondarily (Fig. 1 A and B). The large ulcers of the trochanteric region were closed by means of rotation flaps with undermining (Figs 2 A, B and C). The most difficult problems were the large ulcers of the sacrum in which closure was attempted by means of split-thickness skin grafts. Typical results of this procedure are demonstrated in Figures 3, 4 and 5.

In closure of the small ulcers an attempt was made to remove all the devitalized tissue and all of the scarred tissue surrounding the ulcer by surgical excision. In all these cases, a good five-minute cleansing of the ulcer area was done with white soap and water. The area surrounding the ulcer was undermined


FIG. 2-A
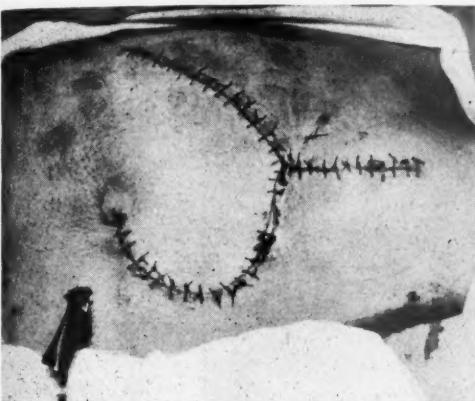
FIG. 2-B   FIG. 2-C

FIG. 2—(A) Preoperative trochanteric ulcer.
FIG. 2—(B) Ulcer at time of operation
FIG. 2.—(C) Two months postoperative.

for several inches in all directions in a normal cleavage plane so that the edges of the defect could be brought together without undue tension. At this time, a stab wound is made at the periphery of the undermined area and a small flat rubber drain is inserted down to the base of the former ulcer. The deep tissues are then closed with multiple, interrupted sutures of No. 00 chromic catgut and the skin edges closed with multiple interrupted sutures of No. 000 silk. A layer of white gauze is applied, followed by a large pressure dressing of mechanic's waste. It was observed that when pressure dressings were not used, sinus formation was frequent beneath the closure.

In dealing with the large ulcers of the trochanteric area, the method of rotation flap was used. It was early recognized that the movement of the greater trochanter caused a constant tearing and sinus formation in the region of the ulcer and contributed largely to the wide undermining process which is common with this type of ulcer. For this reason, during the operation, the patient's legs are carefully padded and bound together in such a manner that the leg on the side opposite to the ulcer in question acts as a splint to prevent rotation of the trochanter under the area. All of the scar tissue surrounding the ulcer is excised down to normal tissue. A pattern is then made of the defect with a

FIG. 3.—Grafted sacral ulcer nine months postoperative.

piece of oiled silk and this pattern transferred to an area adjacent to the ulcer. It has been observed that flaps taken from an area ventral to the ulcer are preferable, because in several dorsally acquired flaps, circulation became jeopardized as the result of skin stretching when the thigh was flexed. The area surrounding the ulcer is now undermined for a distance of several inches and bleeding carefully controlled. The flap is outlined and raised on a normal cleavage plane of the thigh. This entire area is then undermined and bleeding controlled. A stab wound is made in a dependent portion of the undermined area and the flap sutured in place with multiple interrupted subcutaneous sutures of No. oo chromic catgut. It has been our experience that with adequate undermining the donor area could usually be closed without undue

tension. However, in a number of cases, the donor defect was so large that a split-thickness skin graft was required to close a portion of the donor area. The skin edges are then closed with multiple interrupted sutures of No. 000 silk and a rubber drain placed in the stab wound to reach the base of the previous ulcer. It should be noted that in none of the cases was the drain placed through the line of suture. This was considered important, because the area along the suture line is usually somewhat scarred and the line of greatest tension exists at this point. The area of the suture line is the area of previous abnormality and carries the added danger of potential infection. The healing of the stab wound has occurred readily following removal of the drain. Oint-
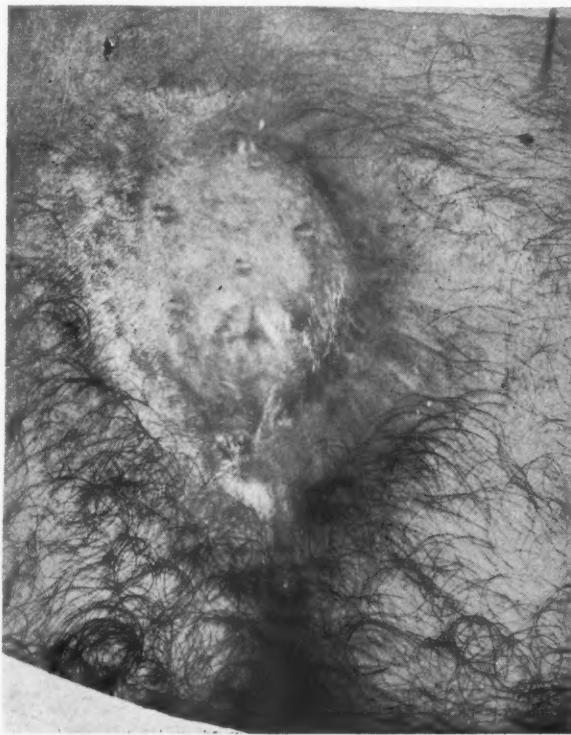

FIG. 4.—Grafted sacral ulcer ten months postoperative.

ment gauze dressing is applied, followed with pressure dressing of sterile mechanic's waste. Following closure of this particular type of ulcer by this technic it is deemed important that a large amount of adhesive tape be applied to prevent undue tension on the suture line by taking up skin slack. It must be remembered that in this group of patients, most without pain sensation, the normal protective mechanism has been lost.

The technic in skin grafting of the large ulcers is as follows: After the ulcer has been débrided down to a fair base, bleeding is controlled with hot saline packs. In a number of cases, local adrenalin has been employed to aid in hemostasis. The grafts are usually taken from the posterior portion of the

thigh, and are of approximately 12/1,000-inch in thickness. Before the graft is placed into position, the granulating area is sprinkled with sulfanilamide crystals. The graft is now laid into position and sutured with a continuous stitch of No. 000 silk around the periphery of the ulcer. Perforation of the graft with multiple small holes allows drainage of serum from beneath the graft. Ointment gauze is applied followed by a pressure dressing with mechanic's waste. This step is considered important to prevent collection of serum or an hematoma underneath the graft. It has been our experience that no difficulties have arisen in healing of the donor area in any of our cases. This is probably due to the fact that the donor skin is acquired from over a fleshy portion of the body which is subjected neither to periods of local ischemia from pressure nor to excessive moisture.

FIG. 5.—Grafted sacral ulcer two months postoperative.

POSTOPERATIVE CARE

The postoperative care of small ulcers, both in the trochanteric and sacral regions, has presented no particular problem. A standard postoperative treatment is being employed in all cases. On the third day postoperatively, the dressings are removed and the area of closure or graft is cleaned with hydrogen peroxide to remove the serous discharge. The area is dried with ether and sulfanilamide powder dusted along the line of closure. A dry pressure dressing of mechanic's waste is then applied. Hereafter, this procedure is done daily

using the same technic, until on the tenth or twelfth day the sutures are removed. At one time in our experiences, ointment dressings were applied following the removal of the original dressing. It was discovered, however, that ointment dressings over a period of several days resulted in maceration at the suture line. The drain is partially pulled out on the third day and totally removed on the fifth day in those cases in which a drain had been employed. There is a considerable amount of serous discharge for the first five days, which is gradually decreased until on the eighth day it should be minimal. The cases in this series received parenteral penicillin for several days postoperatively.

Early in our experience, wet dressings were applied immediately postoperatively in the skin graft cases. This was found to be inadvisable because of maceration of the graft resulting in loss of parts of the graft.

There has been little or no tendency for these surgically closed ulcers to break down. Most cases in the series have been kept under observation for a year and each patient is instructed in the care of his healed graft or closure. The same factors responsible for the occurrence of a decubital ulcer would contribute to recurrence or break-down. These factors are prolonged pressure with resulting local ischemia, excessive moisture and general debility. Training this type of patient to frequently change his position is not difficult, particularly as he is most interested in not having his ulcer recur. We have observed that following successful closure of a large ulcer, the patient's appetite increases and with this increased appetite a sense of well-being occurs. Serum proteins rise and on several occasions negative albumin-globulin ratios have become positive. These phenomena occur too quickly following closure to be considered unrelated to the closure. Local care of the healed closure or graft consists of daily massage with a light oil containing lanolin, frequent position changes and careful avoidance of prolonged contact with body excretions.

DISCUSSION.—The operative results in a series of 70 cases of decubital ulcers have been observed over a period of 12 months and, on the whole, have been satisfactory. Thirty-two ulcers were small in type and were closed by excision and suture. Twenty-eight healed *per primam* and there were four failures. One of these has been reoperated and has healed. Another healed by epithelization. The final results of the remaining two are unknown as the procedures were performed at another hospital.

Nineteen rotation flaps were performed and there were no complete failures. In several cases, a superficial separation of the suture line occurred in a small area which readily healed by secondary intention.

Nineteen skin grafts to large sacral ulcers were performed and 11 healed *per primam*. Six healed partially, and two were total failures. Of the six partially healed grafts, two were reoperated successfully. It is our opinion that a partial take is followed by more rapid epithelization than would occur in a surgically untreated ulcer. This has been observed in those remaining cases classified as total failures.

CONCLUSIONS

Decubital ulcers in paralyzed patients have been treated with primary closure, rotation flaps and split-thickness skin grafts. Donor sites heal readily in those cases in which skin grafts are employed. The closure of a large decubital ulcer is related to an increase in appetite and sense of well-being in the patient. In addition several months of nursing care to a slowing granulating and epithelizing area are avoided. End-results after one year's observation have been satisfactory and the tendency to break-down or recurrence has been minimal in this series.

REFERENCES

[1] Munro, D.: Care of the Back Following Spinal Cord Injuries. The New England Journal of Medicine, 223, 391–398, 1940.

[2] Mulholland, J. H., Co Tui, *et al.*: Protein Metabolism and Bed Sores. ANNALS OF SURGERY, 118, 1015–1023, 1943.

[3] McCormick, W. J.: The Nutritional Aspects of Bedsores. Medical Record, 154, 389–391, 1941.

[4] Vorhaus, M. G., Gompertz, M. L., and Feder, A.: Clinical Experiments with Riboflavin, Inositol and Calcium Pantothenate. American Journal of Digestive Diseases, 10, 45–48, 1943.

[5] Lamon, J. D., and Alexander, Eben, Jr.: Secondary Closure of Decubitus Ulcers with the Aid of Penicillin. J. A. M. A., 127, 396, 1945.

[6] Scoville, W. B.: Personal communication.

[7] Foman, Samuel: Surgery of Injury and Plastic Repair. Williams and Wilkins Co., Baltimore, Md., 1939.

DISCUSSION.—DR. JOSEPH E. J. KING, New York, N. Y.: This most remarkable work done by the young medical officers of the Service and presented to us tonight is truly epoch-making.

At Ashford General Hospital yesterday the young Captain who showed us the paraplegias appeared to be so kindly disposed to his patients, so cordial and encouraging, and he tried to make the boys feel as happy as possible; I was deeply impressed by his attitude. Then we were rather surprised and very much pleased to see the splendid work which had been accomplished in the curing of bedsores, *i.e.*, the skin grafts and flaps.

In our service during the last War most of the paraplegias resulting from gunshot wounds slowly died of an ascending infection after lingering on the wards for a considerable period of time. It goes without saying we did not have the advantage of the new drugs and Munro's tidal drainage was unknown. Treatment of paraplegias has vastly improved at the present time. Even so, many of these young men will be invalids for life and will be unable to marry and have children. They do not present the hopefulness shown by most of the other wounded men, although they may be amputees, or may have sustained other serious or disabling injuries of the chest, abdomen, peripheral nerves, *etc.* This latter group may go home in good fettle and happy, and continue so through life. It is my belief that the paraplegias, for the most part, will not be able to do this; many of them will sit or lie around in invalid state.

After the last War I was connected with the Veterans Bureau for about 13 years and, in a number of instances, have seen the men's compensation cut down from $150 per month to as little as $8 a month in claimants who had not improved in the interval. I feel that an especial effort should be made on our part to see that this particular group of patients receives full and just compensation for their injuries. At the present time our government is spending a great sum of money for all sorts of things, and I know of no better use to which to put it than for the care and welfare of these unfortunate soldiers.

COL. R. GLEN SPURLING, Washington, D. C.: I feel that I should say a few words about the program for the future being planned for these patients. I am sorry that

clo-
y in
pital
ent.
and
ave
een

our-

s of

389-

vin,
10,

with

Co.,

ork
ruly

the
ing,
his
ork

hot
on-
the
has
lids
ful-
nay
es,
igh
is;

ars
150
al.
oup
me
ow
ate

ds
at

General Rankin and Colonel Woodhall could not have been here to speak, for they have played such a vital part in planning it.

Many of these patients are going to require hospitalization for years to come. Others are soon going to find their niche in a civilian economy, quite independent of any Army or Veterans hospital care. The beautiful demonstration of professional achievement you have heard here today is but one part of the program. I wish that you might have seen the tremendous strides that have been made in rehabilitating them from bed invalids to a useful ambulatory status. The transition from a bed to a wheelchair existence is not enough; they actually walk, learn productive vocations and cultural avocations. They even learn to drive automobiles quite independently. They are going to do a lot of things that will make life worth while.

Many of the complete lesions are going to continue to be Veterans Administration problems once they have received maximum benefit in Army hospital installations. Looking forward to this, we have plans for setting up four or five Paraplegic Centers to carry on this work of rehabilitation. In fact, if the present plan fully materializes, the Veterans Administration hopes to take over five Army hospitals, into which these patients have been concentrated, so that there will be a minimum amount of disruption of the training program. It is General Hawley's plan to give them everything Doctor King wants them to have; every modern educational and occupational aid to make them a happy group of people.

Dr. Walter C. G. Kirchner, St. Louis, Mo.: Relative to the papers presented, I would like to show similar problems as they occur in civilian life, and how the handling of some of the lesions might also apply to cases in Army practice.

This first slide represents a roentgenogram which shows a pronounced dislocation and fracture of the lumbar vertebrae, and the second slide, the result after three weeks, traction having been applied, and it will be noticed that an improvement has taken place in the alinement of the vertebrae.

In the third slide are seen extensive decubitus lesions in a case of spinal cord damage.

An important factor in the treatment of spinal cord injuries in the home is the use of a proper type of bed and a suitable Balkan frame, as illustrated in the next slide. In addition to a means for elevation of the trunk and lower extremities, provision is also made for the lowering of the midportion of the bed to enable an easier use of the bedpan. The bed is independent of the Balkan frame. Even in the home, after instructing the wife of the patient, satisfactory care of the bladder and bowels may be had when a proper type of bed is installed.

I have found the use of the plaster shell a valuable aid in the treatment of injuries of the spine. While offering protection and the ability of more easily handling the patient, it adds to his comfort, and it is a means of preventing and also of curing bedsores. The slide shows the shell in position, which also permits treatment of bedsores.

The satisfactory treatment of bedsores is based upon the principles of wound healing. Careful studies have shown that healing takes place not only by an advancing of the epithelium, but also the entire thickness of the skin advances in an effort to close the wound, when the gaping is not too large. There are two forces at play, centrifugal and centripetal, the one causing the wound to enlarge, the other encouraging closure. When the force which aims at closure is greater than the centripetal force there is a tendency on the part of nature to promote healing. Taking advantage of nature's method of healing the wound, closure of the bedsore is promoted by the use of adhesive strips, so applied that by stretching of the skin, approximation of the edges is encouraged. At intervals of several days the strips are reapplied, one at a time, and it is surprising to notice that large bedsores are made to heal with but a small residual scar which, by means of massage, may be made free and mobile. The slide shows the result of healing of a bedsore large enough to expose the rectum.

In the home, the wife often makes a most satisfactory nurse, and I have under my care a case of complete paraplegia, in which, with the aid of the wife, attention to the bowel and catheterization has been performed for a period of more than 23 years, and in spite of this great handicap the patient has learned a trade and is self-sustaining.

Admiral W. M. Craig, Bethesda, Maryland: This has been a very stimulating symposium and I want to congratulate the essayists on their presentation. The Navy program

in the treatment of these cases has been very similar in that they have been more or less concentrated in the Centers where they could receive the combined care of the neuro-surgeon, orthopedist, the urologist and the physical therapist and vocational therapist. I can add my hearty and sincere second to the remarks made by Doctor Gage regarding these cases, in that their rehabilitation has been one of the outstanding medical contributions of this War. These veterans suffering from spinal cord injuries resulting in permanent loss of motor and sensory function, as well as bladder and bowel dysfunction, are far better off than were the veterans of the last War and the civilians who were treated in the prewar years.

The Navy has been interested in improving the condition of the bladders of these cases by instituting transurethral section of the internal sphincter. This has been done in certain cases where there was difficulty in emptying the bladder, resulting in retention or the presence of marked residual urine. While insufficient time has elapsed to evaluate the permanent results, yet the cases we have had at the National Naval Medical Center have shown most gratifying results. A much larger series of cases has been done on the West Coast and the reports we have had are most encouraging and we can hope that this procedure will add to the program of rehabilitation of these cases as presented at this meeting.

DR. EDWARD H. RAY, Lexington, Ky.: I had the fortunate experience of visiting Newton D. Baker General Hospital a few months ago and of seeing the beautiful work being done there. I also had the chance of observing the paraplegia wards at Nichols General Hospital, where I was in charge of the Urologic Section for three or four months, and the contrast between the general condition of the patients at the former, where streptomycin was being used, and that of those at the latter where no streptomycin had been available, was great. Without streptomycin the morbidity from urinary tract infections and from renal calculi was marked. Shortly before leaving the service I received a supply of streptomycin and found it to be just as valuable as has been indicated by Major Petroff.

Admiral Craig has mentioned the bladder neck obstruction that occurs in many of these patients and the fact that transurethral resection affords relief in many instances. It has been very interesting to study this condition in such a large group of patients. With a complete lesion of the spinal cord an automatic type of bladder usually develops, so that it is able to empty itself with varying degrees of completeness.

There is no true internal urethral sphincter, but there is a pseudosphincter formed by fibers of the detrusor muscle which extend in swirl-like fashion into the posterior urethra. The effort made by the automatic bladder to empty itself results in an hypertrophy, not only of the detrusor proper, but of the muscle fibers at the vesical orifice, so that in time a bladder neck obstruction develops with increasing urinary retention. This bar or collar-shaped obstruction lends itself readily to transurethral resection in carefully selected cases, as determined by cystoscopic examination.

I should like to congratulate the essayists on their presentation of this interesting subject. I enjoyed their papers very much.

COL. DAVID H. POER, Martinsburg, W. Va. (closing): I want to thank everyone for their discussion, and I have little to add. We have discussed in detail with you the treatment carried out in Phase II. I had hoped Colonel Spurling would discuss in more detail the treatment of those patients in Phase I, because it seems to me that lowering of the mortality from 50 to 60 per cent in previous wars to 12 per cent in the present war in that phase is particularly noteworthy, and we need to know more of the details; it represents an outstanding accomplishment of the neurologic surgeons.

Phase III definitely presents a challenge and I do not feel that we have answered it. I am not sure that all the plans discussed by Doctor King and others are the right approach. If these patients could only forget their pension, saving it for health insurance that they cannot buy, and develop the idea that they can become self-supporting again, then they are more likely to coöperate and work with you in learning to get about and perfect a trade. It requires a lot of fortitude to do what they must do, and if they need the stimulus of wanting and needing and desiring to support themselves and their families, it is something that apparently can be provided in no other way. We are bound to see individuals who, knowing they have a liberal government check coming in, will have

a tendency to lag, and this is difficult to overcome. I wonder in my own mind if we could not let that government money accumulate for emergencies in the future, and make these men get out and learn to walk and get about, and make a living.

To the orthopedic surgeon particularly, loss of motion in the lower limbs presents a challenge. Already some work has been done in Baker Hospital in tendon transplants and stabilization of joints, and I think the orthopedic surgeons can help considerably in enabling these individuals to get about.

Major Boris P. Petroff, Martinsburg, W. Va. (closing) : The desirable urologic end-result in paraplegics is to dispense with all artificial aids in emptying the bladder, such as suprapubic cystostomies and urethral indwelling catheters. These are avenues of infection which cause unnecessary complications in the urinary tract. Forty patients came to us with suprapubic cystostomies in October, 1944, and by July, 1945, all suprapubic cystostomies had been closed and urethral catheters instituted with tidal drainage according to the method of Dr. Donald Munro. Now 25 out of the 40 are voiding without residual. The remaining 15 with indwelling catheters have not been able to start the urinary stream because of bladder neck obstruction or bladder atony. Five of these have had transurethral resections of the bladder neck and are now voiding without residual. Only a small amount of tissue had to be removed from the ridge of fibrous tissue which had formed between the verumontanum and bladder. Ten patients remaining with urethral catheters will void after their bladder necks are resected, too.

Streptomycin is very important in transurethral resections in paraplegics. If given prior to resection as well as afterward, the possibilities of complications due to overwhelming infection with gram-negative bacilli are greatly reduced, and a smooth recovery is assured.

BATTLE INJURIES OF THE ARTERIES IN WORLD WAR II*

AN ANALYSIS OF 2,471 CASES

COLONEL MICHAEL E. DEBAKEY, M.C.,
AND
LT. COLONEL FIORINDO A. SIMEONE, M.C.

ACUTE INJURIES OF MAJOR ARTERIES, which literally threaten both life and limb, have always constituted a serious problem in the surgical management of traumatic conditions. In times of war, this subject assumes even greater significance, and further impetus is, therefore, provided for the study of the problem and the development of a more effective solution. Although considerable progress was made in this field of surgical endeavor in the interval between World War I and World War II, early experience in the latter conflict soon showed that satisfactory methods of managing arterial injuries were yet to be developed. Moreover, there was little unanimity of opinon concerning either concepts of management or procedures of choice in individual cases. As experience increased and as various technics were tested, increasing difficulty was met in their evaluation because there were no accurate figures on survival expectancy after acute ligation of arteries under war-time conditions. For these reasons, special efforts were made in certain active Theaters of War to study the problem intensively and to collect data which would permit analysis and would provide more definitive information concerning it.

In this report an effort has been made to present as accurately as possible, on the basis of data now at hand, information as to war wounds of the arteries occurring in American Forces during World War II, with respect to incidence, types, location, morbidity, methods of management, and factors influencing the outcome. These data have been obtained from all sources available to the Surgeon General's Office, including special reports from consultants, hospitals and field units, as well as from individual medical officers who have made special studies of arterial wounds. Comparisons of significant data, methods and concepts have been made with those of previous wars whenever it seemed pertinent or desirable.

It should be clearly understood that the data derived from the 2,471 arterial wounds on which this analysis is based pertain only to fresh or acute wounds and not to later and more chronic types of complications, such as traumatic false aneurysm (including the so-called pulsating hematoma) and arteriovenous aneurysm. It is most important to bear this in mind, for much confusion has arisen in the past from failure to define clearly the type and character of the data reported and from the inclusion of acute and chronic lesions in the same reported series.

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4–6, 1945, Hot Springs, Virginia.

INCIDENCE

A search of the literature reveals little information concerning the incidence of wounds of the arteries among battle casualties in previous wars. Generally, the statistics which are available would seem to underestimate the incidence of this type of wound. Even in World War II, when a real effort was made to report the figures accurately, the data are still deficient in certain respects. The lack of information is not difficult to explain: For obvious reasons vascular injury is seldom recorded as a primary diagnosis, and in many instances, including both the most serious and the least serious cases, it is probably not
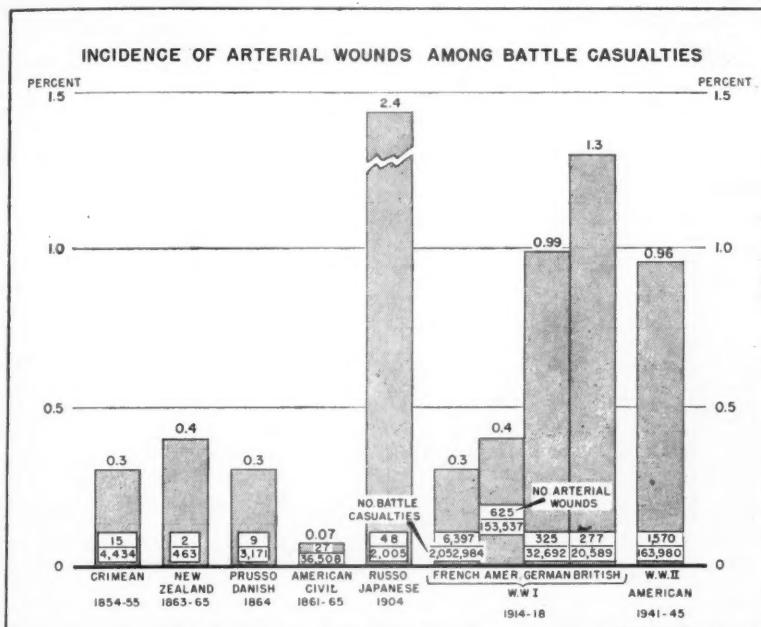

CHART I.—Incidence of arterial wounds among battle casualties in various wars.

recorded at all. In addition, analysis of the available statistics requires considerable caution. Most series are actually or relatively small, and many from previous wars include both acute and nonacute conditions. In drawing conclusions from them, therefore, many qualifying circumstances must be taken into account.

All available statistics (Chart I) suggest that the incidence of arterial wounds among battle casualties in previous wars was extremely low, ranging from 0.07 per cent in the War Between the States to 2.4 per cent in the Russo-Japanese War.[24, 63, 119, 120, 122, 143, 162] LaGarde reported an incidence of 0.8 per cent in 1,400 casualties at Santiago during the Spanish-American War.

From data tabulated in the official American history of World War I the incidence of vascular wounds among American troops has been computed to be 0.4 per cent (Chart I).[120] The British official history,[129] although it devotes considerable space to the subject of arterial wounds, supplies no data concern-

ing incidence, and Makins' classic monograph[128] on gunshot injuries of the blood vessels says nothing on this point. His material, as a matter of fact, is limited to 1,191 cases (Table I) made up of two series; one consists of 668 cases handled by numerous individual surgeons in the British Isles and over-

TABLE I

	BRITISH WORLD WAR I (MAKINA*)				AMERICAN WORLD WAR II			
			Loss of Limb†				Loss of Limb	
	Total No.	% Total	No. Cases	Per Cent	Total No.	% Total	No. Cases	Per Cent
Aorta............:	5	0.4	5	100.0	3	0.12	2	66.6
Carotid...........	128	10.7	38	29.6	10	0.4	3	30.0
External carotid...:					3	0.12	0	00.0
Renal.............					2	0.10	2	100.0
Vertebral..........	3	0.2	0					
Subclavian.......::	45	3.7	4	8.8	21	0.85	6	28.6
Axillary...........	108	9.0	5	4.6	74	0.30	32	43.2
Brachial total.....	200	16.7	12	6.0	601	24.3	159	26.5
Above profunda.:					97	3.9	54	55.7
Below profunda.:					209	8.5	54	25.8
Radial-ulnar......:	59	4.9	3	5.0				
Radial..........					99	4.0	5	5.1
Ulnar..........:					69	2.8	1	1.5
Radial and ulnar...					28	1.1	11	39.3
Common iliac.....:	1	0.1	1	100.0	13	0.5	7	53.8
External iliac......	4	0.3	0	0	30	1.2	14	46.7
Internal iliac.......	1	0.1			1	0.05	0	00.0
Femoral total......	366	30.5	74	20.2	517	20.9	275	53.2
Above profunda.:					106	4.3	86	81.1
Below profunda.:					177	7.2	97	54.8
Profunda.......:					27	1.1	0	00.0
Popliteal..........	144	12.0	62	43.1	502	20.3	364	72.5
Anterial tibial.....:	26	2.2	1	3.8	129	5.2	11	8.5
Posterior tibial.....	97	8.1	9	9.2	265	10.7	36	13.6
Ant. and post. tibial	7	0.6	2	28.6	91	3.7	63	69.2
Peroneal...........	4	0.3	2	50.0	7	0.28	1	14.3
Ant. tibial and peroneal.........	3	0.2	0	0				
Post. tibial and peroneal.........	1	0.1	0	0	5	0.20	2	40.0
Both tibials and peroneals.......					1	0.05	1	100.0
Total........:	1202‡		218	18.1	2471		995	40.3

* The figures compiled from Makins' tables represent combinations of the totals for "gangrene" and "amputations," so that the maximum number was obtained without possible duplications. The numbers represent the minimum number of cases that must have had amputations.

† In case of aorta, carotids, and renal arteries, the figures indicate the numbers that died or developed cerebral complications.

‡ This total differs from the number of 1,191 cases given in Makins' master table, because 11 vessels of the leg were added from a detailed table presented in the text.

seas, and the other of 523 cases similarly handled in France but supervised by a single surgeon. Only modified reliance, Makins warned, could be placed on any deductions drawn from this material, and it contributes nothing to the incidence of vascular wounds among British troops in World War I. The only material available on that subject was found in Bowlby and Wallace's report of 20,589 casualties treated at a single casualty clearing station, 277 of whom (1.3 per cent) required ligation of major arteries.

Maurer[135] recorded 443 wounds of the blood vessels observed among 8,000 wounded treated in a French ambulance service. If the 17 per cent of wounds involving only the veins be excluded, the incidence of arterial injuries is 4.6 per cent. Figures reported by Mignon (so stated that a tabulation was possible) for six French ambulances show 399 vascular injuries (2.02 per cent) among 19,734 wounded. The French official history of World War I[143] shows 6,397 vascular injuries (0.99 per cent) among 2,052,984 wounded. The German incidence, according to Franz, was 0.99 per cent.

Matas,[132] in his exhaustive consideration of vascular injuries, stated that in World War I, 24.7 per cent of battle casualties at the front required treatment for injuries of the blood vessels and added that 2 per cent of all wounded admitted to Base Hospitals presented traumatic aneurysms. These are the highest figures that have been found in the literature for the incidence of vascular injuries among battle casualties, and the source material upon which they were based was not indicated.

TABLE II

CAUSES OF AMPUTATION IN 189 CASES OF VASCULAR INJURY*

	1943		1944–45		1943–45	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Primary			43	32.3	43	22.8
Gangrene...............	47	84.0	64	48.1	111	58.7
Clostridial myositis.......	8	14.0	13	9.8	21	11.1
Other infections..........	1	2.0	13	9.8	14	7.4
Total..............	56	100.0	133	100.0	189	100.0

* Amputations done at initial wound surgery, when vascular injury made survival of limb unlikely.

World War II.—Considerably more data on which to base estimates of the incidence of vascular injuries among battle casualties are available for World War II. Moore stated that the 13 vascular injuries which he treated in a German prison camp formed 0.43 per cent of all hospital admissions. All the patients were seen late (between three and 42 days after wounding) and the circumstances necessarily made the group highly selective. Cole and Neel found nine injuries of major vessels (1.4 per cent) among 638 wounds of the extremities sustained in amphibious warfare in the Pacific.

At the present writing, reasonably complete data are available from armies in three of the most active American Theaters of Operation in different parts of the world. The total incidence of 0.96 per cent (1,570 vascular injuries among 163,980 battle casualties) is remarkably close to the incidences reported from the separate Theaters and armies (Chart 2). The similar correspondence noted in the distribution of vascular wounds among wounds of the extremities observed in the separate Theaters and armies suggests that the over-all incidence of 1.4 per cent is fairly representative (Chart 3).

Incidence in Relation to Amputation.—The total incidence of vascular wounds among all casualties, and even among wounds of the extremities, is both relatively and absolutely small, and even the large numbers of wounded in World War II do not make the total number of vascular wounds very large.

537
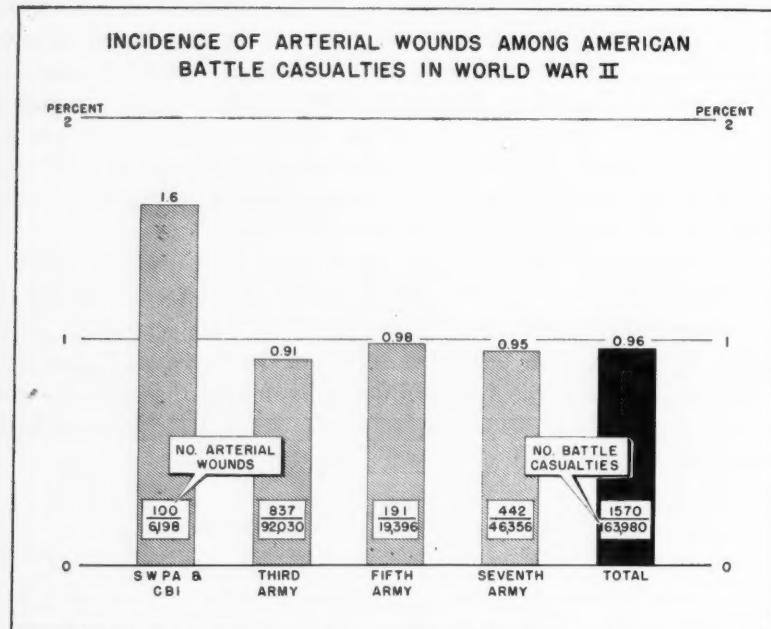
CHART 2.—Incidence of arterial wounds among American battle casualties in World War II.
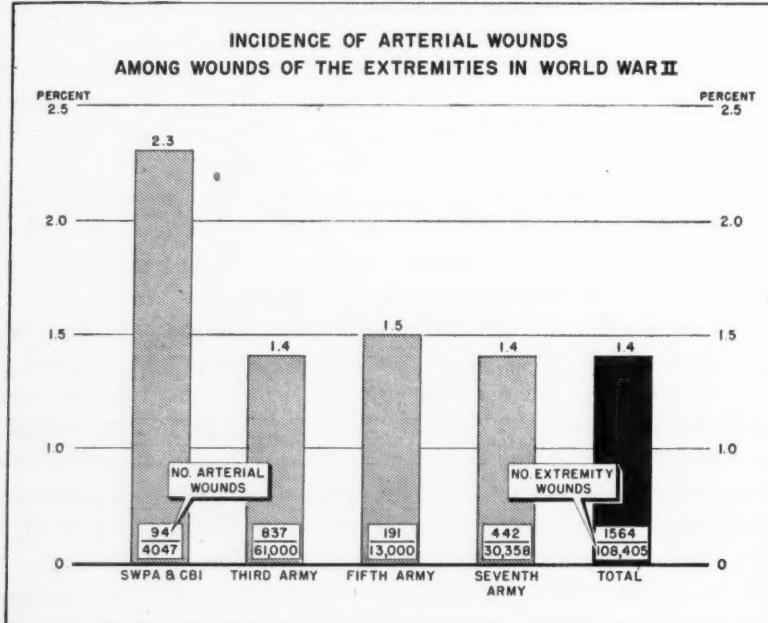
CHART 3.—Incidence of arterial wounds among wounds of the extremities in American battle casualties in World War II.

The real significance of these injuries, however, is better appreciated by examining the frequency with which they appear as a cause for amputation.

No significant statistics compiled from this point of view have been found in the literature, but accurate data are available from the Mediterranean and European Theaters of Operation (Chart 4). Among 3,177 major amputations from these Theaters, 2,179 (68.6 per cent) were the result of extensive trauma, 380 (11.9 per cent) were the result of clostridial myositis or other serious infections, and 618 (19.5 per cent) were the result of major arterial injuries. Figures which became available with the capture of a German amputation Center showed that among 1,359 major amputations, 64.3 per cent were the

CAUSES OF AMPUTATION AMONG AMERICAN BATTLE CASUALTIES IN WORLD WAR II
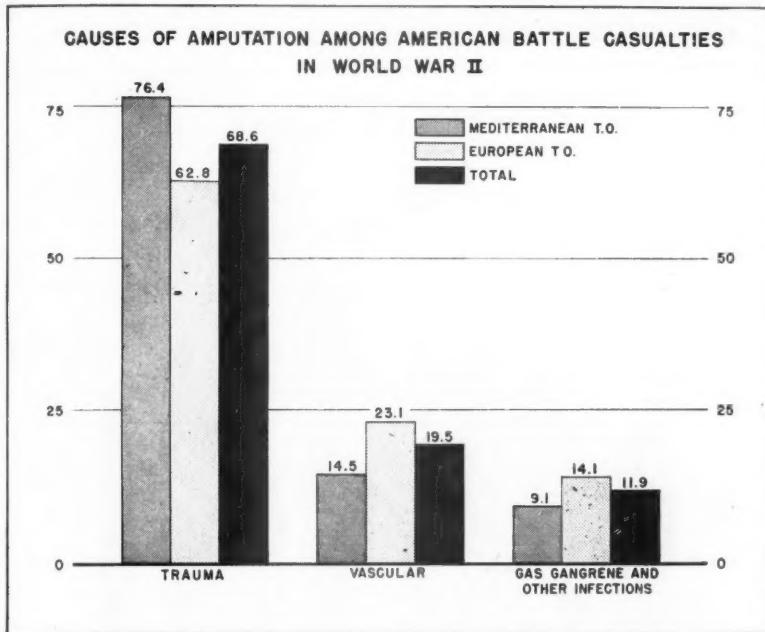
CHART 4.—Causes of amputation among American battle casualties in World War II.

result of trauma, which is close to the American incidence of 68.6 per cent. Only 6 per cent, however, were the result of vascular injuries, while 29.7 per cent were the result of clostridial myositis. Corresponding figures on the Russian experience have been reported by Kramarov, who observed that trauma was the cause for amputation in 16 per cent of the cases, vascular injury in 5 per cent, and gas gangrene and other infections in 79 per cent. The far smaller incidence of the latter in the American statistics is a reflection of the highly creditable standards of surgery achieved by American surgeons in Forward Areas.

The figures which have been presented in this section provide a much better perspective of the vascular problem in war surgery than has previously been possible. For one thing, they provide a true concept of the magnitude of the

problem. For another, they make clear that the great majority of amputations are inevitable and beyond the surgeon's control. Therapeutic measures designed to save the limb are clearly applicable, at best, to not more than 20 to 25 per cent of all such injuries, which should put to rest the overenthusiastic and even extravagant claims occasionally made as to the possibilities of salvage of limbs in battle wounds of the blood vessels.

Regional Distribution of Vascular Injuries.—An analysis of the relative frequency with which various arteries are involved in battle casualties (Chart 5, Table I) shows that the brachial, tibial, femoral and popliteal arteries are involved far more frequently than any others. They accounted for 70 per cent of the total vascular injuries reported by Makins and for 85 per cent of the vascular injuries sustained by American troops in certain Theaters of Oper-

INCIDENCE OF WAR WOUNDS OF ARTERIES
ACCORDING TO LOCATION

BRACHIAL   FEMORAL
TIBIAL   POPLITEAL

CIVIL WAR 1557 CASES: 35.4, 16.8, 17.3, 6.7
W.W. I AMERICAN 334 CASES: 23.3, 25.7, 21.3, 8.1
W W I BRITISH 1066 CASES: 34.3, 18.8, 13.0, 13.5
W W II AMERICAN 2301 CASES: 21.1, 24.5, 20.3, 20.6
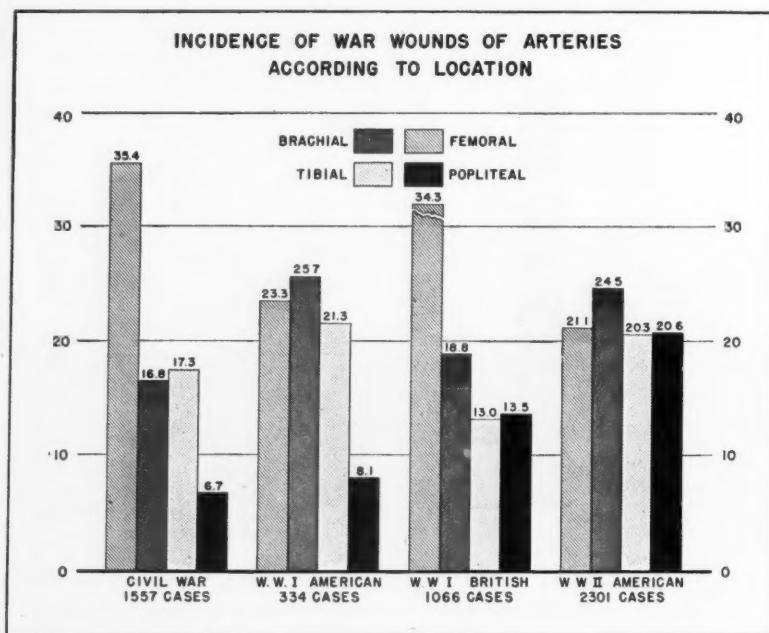
CHART 5.—Distribution according to site of arterial wounds of the extremities in various wars. These incidences, it should be emphasized, are based only on arterial wounds of the extremities, whereas those shown in Table I are based upon all arterial wounds.

ation in World War II. The explanation of this preponderance is simple: Casualties suffering from injuries of larger arteries frequently do not live long enough to reach medical installations (and, therefore, do not appear under precise diagnoses in medical statistics), while injuries of less critical arteries are frequently not discovered at all, or, if discovered, are not recorded.

A comparison of the incidences of wounds of the brachial, tibial, femoral and popliteal arteries in the War Between the States, World War I (British and American statistics) and World War II (American statistics) shows a relatively close order of magnitude of the incidences of wounds of these four

arteries in World War II as compared with earlier wars, and a much higher incidence of popliteal injuries in the recently terminated war as compared with previous wars. The explanation for these differences can be only conjectural. It may lie in more exact methods of recording, in a greater and more selective interest in vascular injuries, and perhaps in the more conservative surgical policies directed toward conservation of limbs in World War II.

THE THERAPY OF VASCULAR INJURIES
GENERAL CONSIDERATIONS

Any discussion of the therapy of vascular injuries must begin with the premise that the restoration of the flow of blood through the original channel is the desideratum. Unfortunately, even in civilian traumatic surgery, this can be accomplished in only a limited number of cases, while in military surgery
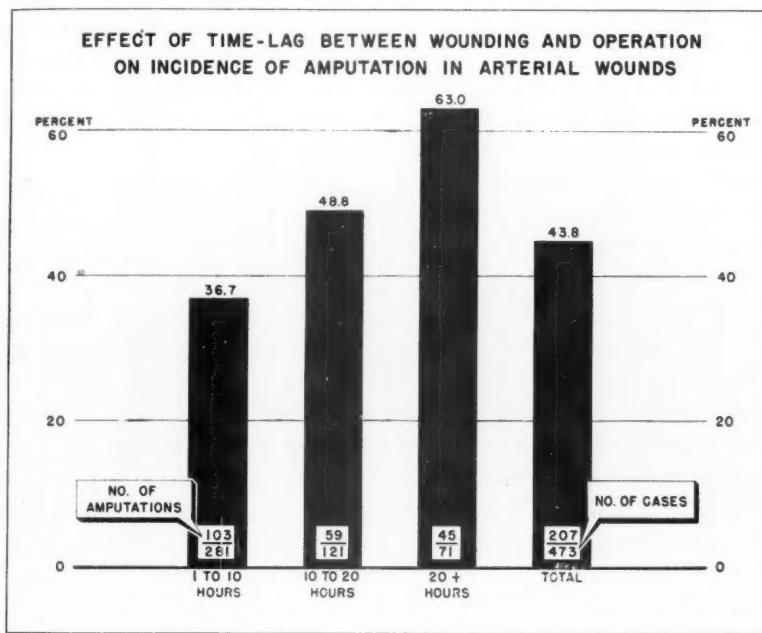
CHART 6.—Effect of time-lag between wounding and operation on incidence of amputation in arterial wounds of the extremities among American battle casualties in World War II.

the number is even more limited for certain definite reasons enumerated below. Essentially, these reasons may be divided into two categories: (1) Those in which the factors are of such vital significance that they seal the fate of the limb regardless of any form of therapy; and (2) those which jeopardize the effects of ideal therapy or preclude its institution.

Time-Lag.—Ideal therapy, designed to reëstablish the circulation of the limb, must be done within a limited period of time after wounding. The general (arbitrarily set) limit is six to eight hours. The time-lag in military surgery, however, is predominantly a military matter. Even under the happiest

circumstances the time-lapse between wounding and treatment in the majority of injuries averages over 12 hours.* After such a lapse of time, regardless of the nature of the original wound, thrombosis has probably occurred in the vascular tree distal to the injury and the tissues of the wounded extremity have been deprived of oxygen and nutrition too long a time for the changes to be reversible.

In the material from the American armies studied from this point of view, only a negligible number of patients were seen much earlier than ten hours after wounding, which explains why the results in the one-to-ten-hour category are not very much better than for the group as a whole (Chart 6). Infection is probably not an important factor in this category, though it plays an increasingly important rôle after the ten-hour period and undoubtedly accounts for at least a portion of the unhappy results in the group observed 20 hours or more after wounding. On the other hand, from the standpoint of possible reëstablishment of the circulation, it is questionable whether a time-lag of more than ten hours is of special significance, since, as already pointed out, procedures designed for this purpose must be instituted within the upper limits of this period if good results are to be anticipated.

From the military standpoint, it is doubtful that the time-lag can be greatly reduced. Nearly half of it* is taken up by the period between wounding and the administration of first aid. In World War II every effort was made to bring surgical care as near the front lines as possible, so as to cut down the time-lag, but it is highly unlikely that it could be instituted at the Battalion Aid Station level, or that it should be. The best that can be done is not always the best thing to do.

The establishment of vascular wounds as a special category, to be handled by a special routine, also does not seem practical.[156] For one thing, for such a classification to operate effectively would require of medical corpsmen a degree of differential diagnostic skill which they could not be expected to possess. For another, vascular injuries constitute such a small proportion of the total wounded that the imposition of another special category on the already overburdened military organization would seem scarcely justified.

Methods to preserve the circulation until patients with vascular injuries reach installations at which specialized surgery can be done are simply not practical. Supplemental sympathectomy, for instance, would be done with much greater difficulty in a Field Hospital than in a civilian hospital, and sympathetic block is open to the same criticism. The use of heparin before the patient reaches a hospital installation with laboratory facilities would be most unsafe, in view of the precautions necessary when any variety of anticoagulant therapy is employed, and might have disastrous consequences.

---

* In a group of 104 "first priority" patients studied in the Mediterranean Theater, the time-lapse from wounding to arrival at the first hospital installation (Field Hospital) varied between one and 34.5 hours and averaged 12.5 hours. The average time-lag between wounding and tagging (first aid) varied between a few minutes and 25 hours, and averaged five hours. The time-lag from arrival in the hospital to operation varied between one and 10.75 hours and averaged 3.75 hours. In a sample of 58 cases with vascular injuries, the time-lag between wounding and surgical treatment averaged 15.2 hours.

Practical Difficulties.—Ideal vascular surgery is difficult surgery. It requires special equipment, a great deal of time, and, on the part of the surgeon, highly specialized experience and dexterity.[49] The exigencies of the military situation are such that patients are not invariably seen by specialized personnel in the most Forward Installations. In Battalion Aid Stations they are observed by nonspecialized medical personnel, and occasionally only by military administrative officers; neither group is fitted or equipped to institute specialized treatment. Furthermore, even when they reach installations at which definitive surgery can be done, the ablest surgeons cannot produce
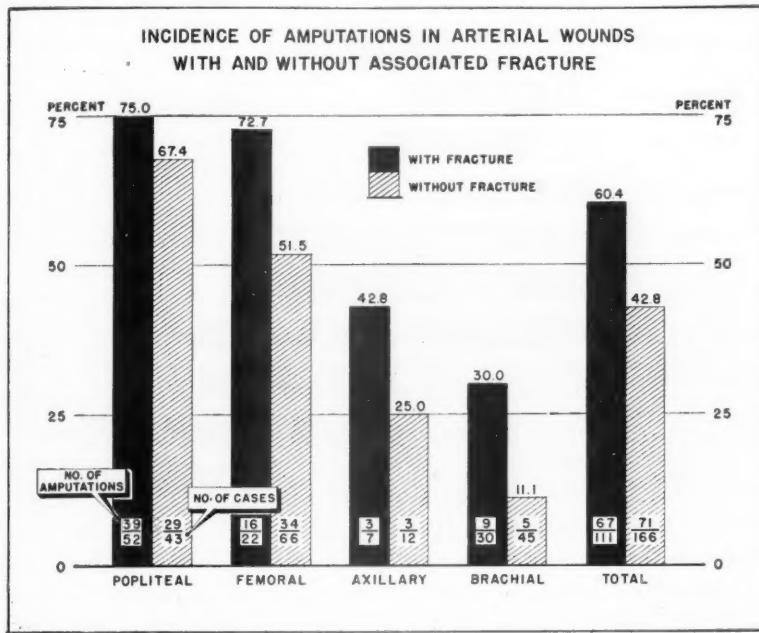
CHART 7.—Effect of presence or absence of associated fractures on incidence of amputation in arterial wounds of the extremities among American battle casualties in World War II.

outstanding results when they are working against factors beyond their control which, as will be pointed out, determine, far more than what they do, the outcome in any given series of cases.

Associated Injuries.—Vascular wounds, like all other battle wounds, occur singly in not more than two-thirds of the cases. They may be associated with other local wounds, which further impair or perhaps completely destroy the regional circulation. They may be associated with more remote wounds, some of which may require attention far more urgently, as a life-saving matter, than does the vascular wound; ideal vascular therapy must frequently be deferred for such a reason. Moreover, even if the vascular wound is single, the patient may be in such poor condition from exposure, loss of blood, or other causes that ideal vascular surgery must be postponed until he is in condition to withstand it. In other words, important as is the salvage of a limb, the salvage of life necessarily takes precedence of it.

To determine the possible effect of associated injuries, the presence or absence of fractures was studied, in relation to the outcome, in the material from the American armies (Chart 7). The incidence of amputation was significantly higher in the group in which vascular injuries were complicated by fractures, which suggests, in addition to the absolute significance of the observation, the importance of knowing all the circumstances about series of cases before drawing conclusions from comparative studies.


INCIDENCE OF AMPUTATION FOLLOWING WOUNDS OF THE ARTERIES OF THE EXTREMITIES

TOTAL CASES — 18.1 / 40.3
BRACHIAL (TOTAL) — 6.0 / 26.1
SUBCLAVIAN — 8.8 / 28.6
RADIAL AND ULNAR — 39.3
AXILLARY — 4.6 / 43.2
EXTERNAL ILIAC — 46.7
COMMON ILIAC — 53.8
FEMORAL (TOTAL) — 20.2 / 53.2
ANTERIOR & POSTERIOR TIBIALS — 28.6 / 69.2
POPLITEAL — 43.1 / 72.5

AMERICAN W.W. II EXPERIENCE
BRITISH W.W. I EXPERIENCE

0   25   50   75
PERCENT AMPUTATIONS

CHART 8.—Effect of site of arterial wounds of the extremities on incidence of amputation in American battle casualties in World War II and in British battle casualties in World War I.

Another consideration which might be mentioned at this time is the amount of blood the patient has lost. In the majority of vascular wounds there has usually been a considerable loss before first aid can be instituted. In a sample group of 27 patients studied a week after wounding, the red blood cell count still averaged only 2,700,000 per cu. mm., and the hemoglobin concentration in 24 of the cases was still only 60 per cent of normal, despite the fact that these patients had received whole blood in amounts that had been thought adequate. One of these patients, with a wound of the femoral artery, had lost 40 per cent of the normal blood volume when he was first seen.

Naturally, if the volume of the circulating blood is reduced, the amount of blood which passes through the peripheral arteries is also reduced, the circulation of the distal portion of the extremity with a vascular injury is still further reduced, and its nutrition suffers correspondingly. From both the systemic and the local standpoints a most important consideration in the therapy of vascular wounds is the prompt restoration of the circulating blood volume

and the hemoglobin concentration. The point deserves to be emphasized, for it is frequently forgotten that the patient with a wound of the extremity often requires an equal or even greater quantity of blood than a patient with a wound of the chest or the abdomen.

Site of Wound.—On the basis of actual experience and under the conditions or limitations imposed by military practice, the categoric statement can be made that the site and type of the vascular wound determine the therapeutic procedure and, therefore, predetermine, so to speak, the end-results. The American experience in World War II, as well as the British experience in World War I when detailed statistics were available for analysis (Chart 8), make clear that wounds of certain vessels, such as the popliteal artery, are much more likely to be followed by ischemic gangrene than are wounds of certain other vessels, such as the brachial artery. Indeed, for practical purposes it is possible to make up categories of critical and noncritical arteries. On the other hand, while a wound of either the anterior or the posterior tibial artery alone was relatively noncritical in the material studied, wounds involving both arteries resulted in the second highest proportion of gangrene in both the British and the American material. Generally speaking, lesions in the lower extremity are more serious than lesions in the upper extremity (Chart 9). A comparison of the incidence of amputations following wounds of the major arteries of the upper extremities (from the subclavian through the brachial) with those of the lower extremity (from the iliac through the popliteal) makes this clear. Furthermore, where the brachial and femoral arteries are concerned, whether the injury is above or below the profunda branch (Chart 10) plays an important rôle in the incidence of amputation. If the cases in which only single vessels of the forearm and leg (radial, ulnar, anterior and posterial tibial, and peroneal arteries) are excluded from the 2,453 arterial wounds of the extremities collected from American armies in various Theaters of Operation (Table I), the incidence of amputation after vascular injury rises to 49.6 per cent. If only wounds of the iliac, femoral and popliteal arteries and multiple arterial wounds of the leg are considered, it rises to 62.6 per cent (Table I). The British figures for World War I are similarly striking (Table I).

As these various figures show, in any unselected group of vascular injuries the proportion of poor results will be high or low, according to the number of important or unimportant vessels involved. The surgeon has no factor of choice, and, therefore, no responsibility, in this respect. The site of the wound is not of his selection, but he must necessarily institute therapy in reference to its location.

Type of Arterial Lesion.—The type, which to some extent is concerned with the size, of the arterial wound, has a two-fold importance: its effect upon the adequacy of the circulation in the distal portion of the wounded extremity, and its influence upon the type of surgical procedure possible. Generally speaking, the larger the injury, (1) the greater the chance that the collateral circulation will be damaged; (2) the more extensive the necessary débridement; and (3) the greater the chance of infection if débridement is not adequate.

INCIDENCE OF AMPUTATIONS FOR ARTERIAL WOUNDS
AMONG AMERICAN BATTLE CASUALTIES IN WORLD WAR II

|		
TOTAL CASES	40.3	988/2453
TOTAL EXCEPT VESSELS OF FORE-ARM AND LEG	49.0	857/1759
TOTAL UPPER EXT.	24.0	214 ← NO. AMPUTATIONS / 892 ← NO. VASCULAR INJURIES
TOTAL LOWER EXT	49.6	774/1561
SUBCLAVIAN THROUGH BRACHIAL	28 3	197/696
ILIAC THROUGH POPLITEAL	62.1	660/1063

0   20   40   60
PERCENT OF TOTAL

CHART 9.—Effect of site of arterial wounds of the extremities on incidence of amputation in American battle casualties in World War II.

INCIDENCE OF AMPUTATION FOLLOWING WOUNDS OF
BRACHIAL AND FEMORAL ARTERIES ABOVE AND BELOW
THE PROFUNDA BRANCHES

BRACHIAL ARTERY   FEMORAL ARTERY

PERCENT   PERCENT
80   81.1   80

60   60

                    55.7   56.1   54.8

40   40

20   26.5   25.8   20
                          NO. OF
                          AMPUTATIONS
      159   54   54   NO. OF CASES   275 86   97
      601   97 209   490 106 177
0   0
   TOTAL ABOVE BELOW   TOTAL ABOVE BELOW
         PROFUNDA   PROFUNDA
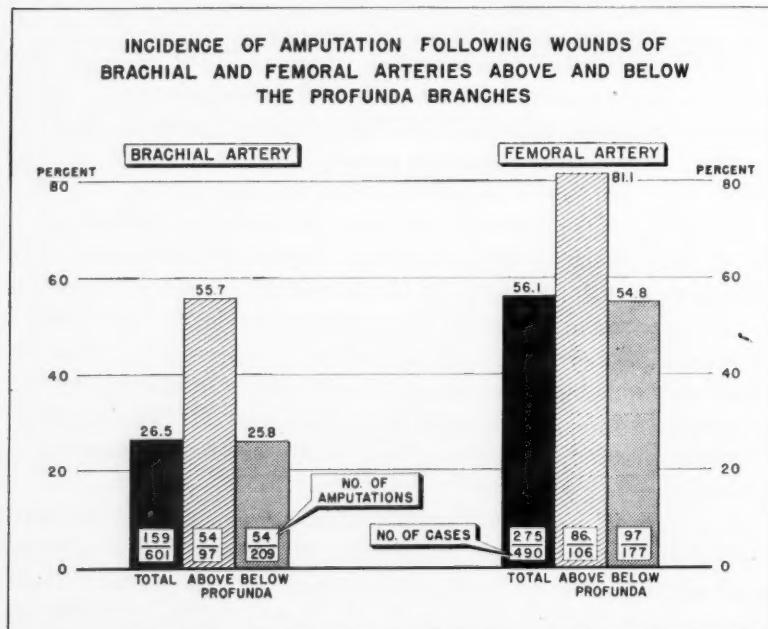
CHART 10.—Effect of site of wounds of the brachial and femoral arteries on incidence of amputation in American battle casualties in World War II. The 27 cases involving the profunda femoris (Table I) have been excluded as not pertinent to this consideration.

In the American material, in the 620 cases in which the records were suffi-
ciently explicit to permit separation of the injuries into distinct categories
(Chart 11), the incidence of amputation seemed definitely related to the type
of lesion. It varied from 25 per cent in spasm to 70.5 per cent in thrombosis.
A high incidence of poor results would be expected in the thrombotic category,
since this type of lesion is likely to cause widespread interference with the flow
of blood through the collateral vessels. In the category of spasm are included
the few cases of contusion which were recorded as such, because contusion,

INCIDENCE OF AMPUTATIONS ACCORDING TO
TYPE OF LESION IN ARTERIAL WOUNDS

TOTAL CASES	$\frac{251}{620}$	40.5
SPASM	$\frac{7}{28}$	25.0
LACERATIONS	$\frac{62}{200}$	31.0
LACERATIONS & TRANSECTIONS	$\frac{207}{538}$	38.5
TRANSECTIONS	$\frac{130}{253}$	51.4
COMPRESSIONS	$\frac{6}{10}$	60.0
THROMBOSIS	$\frac{31}{44}$	70.5

PERCENT AMPUTATIONS   0   25   50   75
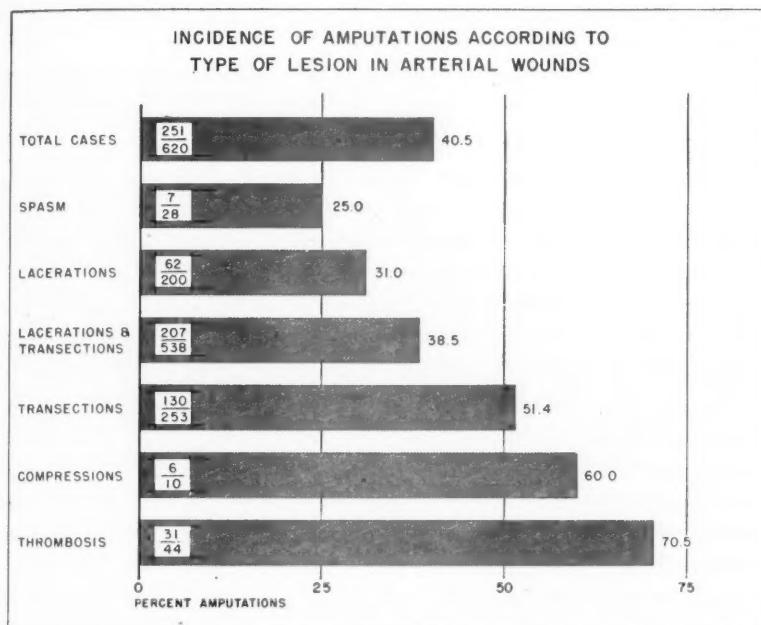
CHART 11.—Effect of type of arterial wounds of the extremities on incidence
of amputation in American battle casualties in World War II. The total num-
ber of lacerations and transections is greater than the sum of the individual
lesions in this category because it could not be determined from 85 of the records
which of these particular lesions was present.

if it is recognized at all, is not infrequently accompanied by spastic phenomena.
This type of lesion, however, is usually not recognized (and, therefore, not
recorded) and is usually slight. Its inclusion in a tabulated series is, therefore,
likely to alter the results favorably, which is perhaps one reason why Makins'
figures, which include contusions, are so much better than other series which
omit them. Some doubt exists as to the incidence of 25 per cent of amputation
in spasm. These figures are undoubtedly weighted, for in one sample of six
cases, there were five instances of gangrene. This is so contrary to the usual
experience as to suggest that the diagnosis of spasm was probably not correct
in one or more of the cases in this group.

The majority of cases of laceration in this series (Chart 11) were serious.

547

Minor lateral lacerations, in which conservative surgery was possible, were relatively few.

The category of lacerations and transections (which includes the 200 cases of lacerations, the 253 cases of transections, and a number of cases in which it could not be positively determined which of these lesions was present) presents an incidence of amputation which, as would be expected in view of its composition, lies midway between the incidence in lacerations, in which there may be a limited interference with the circulation, and the incidence in transections, in which there is abrupt interruption. Clean-cut transections were not the rule, there being tearing and loss of substance in most cases, associated with extensive damage to the collateral circulation.

The compression category includes only a small number of cases, so that the results are not statistically significant. Experience shows, however, that this is a very important group, because such injuries commonly complicate fracture and posterior displacement of the lower end of the femur. If this type of fracture, with its associated arterial lesion, is recognized and appropriate corrective steps are taken promptly, the complications which result from arterial compression can be avoided.

It seems scarcely necessary to elaborate further the importance of the type of wound in relation to the possible surgical procedure. As already intimated, the location and the type of the injury determine above everything else what the surgeon can do. The great majority of the wounds in the World War II series were produced by shell fragments, were large, were associated with extensive destruction of tissue, and (Charts 8–10) were not favorably located (Fig. 2). As a result, the vitality of the limb was gravely impaired before the surgeons ever saw most of the patients, thus jeopardizing the potential benefits of any therapeutic procedures employed.

Infection.—Infection is perhaps the least important of the limitations on therapy imposed by the circumstances of modern warfare. All battle wounds are potentially infected, it is true, but if adequate débridement can be done, surgical procedures directed toward the treatment of the vascular injury can be done at the same time with a high degree of safety. It is not infection, but the other circumstances just outlined, which now prevent reparative procedures in most battle injuries of the blood vessels.

It is granted that the views expressed in this section are extremely pessimistic. They are, however, equally realistic. In their defense it may be said that military surgery can be conducted only on a basis of profound realism, and that war is never a cheerful business.

THE RESULTS OF ACUTE OCCLUSION LIGATION OF THE MAJOR ARTERIES

The results of acute occlusion of major arteries in war wounds, whether caused by the injury itself or by ligation of the injured vessel, have not been clearly established. There are a number of explanations for the confusion which still exists on this subject.

Perhaps the most important reason is the fact that statistics generally quoted as representing the incidence of gangrene after acute traumatic occlusion actually represent no such thing, since most of them include instances of aneurysm as well. The two lesions are, of course, totally dissimilar. In acute occlusion (ligation) the blood flow is cut off abruptly. In aneurysm the occlusion occurs gradually, if at all, and by the time it has developed, or the aneurysm is excised, a more or less adequate collateral circulation exists.

Furthermore, in many series gangrene is the only unfavorable result recorded. The percentage of cases in which primary amputation had to be done because of the arterial injury is completely disregarded, and such series, therefore, do not truly represent the incidence of poor results in acute traumatic arterial occlusion. As for the various series in which amputation is included, the range is so clearly unreasonable—in popliteal arterial occlusion, for instance, it varies from 0 to 100 per cent[142, 157]—it is difficult to determine on what possible basis the calculations have been made.

Makins'[128, 129] statistics, which represent the largest collective experience in World War I, furnish an excellent example of the confusion which results from the inclusion of both acute and nonacute (aneurysmal) lesions in a single series. Actually, 49 per cent of his cases are aneurysms, and in certain vessels, such as the axillary and subclavian arteries, the proportion of nonacute lesions is more than 70 per cent. When (so far as possible) the favorable influence of aneurysm is excluded, his proportion of poor results rises from 18.1 per cent to 26.5 per cent. Yet his figures are repeatedly quoted, without qualification, as showing the incidence of gangrene after acute arterial occlusion. A similar lack of clarity is evident in the series collected by Salomon, Soubbotitch and others.[15, 51, 69, 71, 72, 74, 77, 78, 83, 102, 104, 175, 211] On the other hand, among 74 acute arterial lesions collected by Franz from German World War I statistics, the percentage of gangrene was 70.4. Mocquot and Fey also emphasized the gravity of these wounds, reporting an amputation incidence of 44 per cent among 61 they observed in a French Surgical Ambulance.

No large series of cases is available from the period prior to World War I to show the effect of ligation of major arteries in acute injuries. Sencert,[187] using statistics published before 1914, reported that the incidence of gangrene under these circumstances ranged from 5 per cent in the subclavian and brachial arteries to 50 per cent in the common iliac artery, the astonishingly wide range being explained, as the author himself pointed out, by the inclusion in the series of both aneurysms and acute occlusion.

On the basis of his personal military experience, Sencert[188] reported, in 1918, that ischemic gangrene had occurred only twice in 70 cases of vascular injury in which ligature was done a few hours after injury and in which no hematoma of any significance was present. The figures are confused, however, by the inclusion of four cases in which only veins (two internal jugular, two popliteal) were injured. When a diffuse hematoma had formed, the results were much less satisfactory; of 20 cases in which the axillary, femoral and

popliteal arteries were involved, gangrene developed in six. Sencert's own pronounced views as to the important rôle of hematoma formation in arterial injuries perhaps make the figures somewhat selective.

The results in Makins'[128, 129] British cases collected in World War I are considerably better than the American figures collected in World War II (Chart 8, Table I). The data, however, are not fairly comparable, for a number of reasons: (1) The American figures include only acute lesions, while, as already noted, the British figures include both acute and nonacute lesions. (2) In 85 per cent of the American material the wounds involved important or critical arteries, while this was true of only 70 per cent of the British material (Chart 5). (3) It is possible, though exact statements cannot be made on this point, that there are excluded from the British figures some cases of gangrene and amputation which were classified as infections rather than as vascular injuries, as well as cases in which amputation was necessary for extensive trauma and other complications of vascular injuries. The American figures include among the poor results all the cases in which amputation was necessary after vascular injuries, whether as the result of complicating infection, so-called toxic absorption, gas gangrene, or any other cause. (4) Because of the more destructive weapons used in World War II, it may be assumed that tissue destruction was greater in the American cases of World War II than in the British cases of World War I. As a result, in addition to the main arterial injury, the collateral circulation was frequently and seriously impaired. (5) Because the wounds of World War II were more extensive than in World War I, débridement, which probably was more commonly practiced in the war just ended was a more extensive procedure. This comment must not be misunderstood. Débridement is an essential procedure, the omission of which would undoubtedly have resulted in a higher mortality rate, as well as in the loss of more limbs from infection. When properly done, however, it involves loss of tissue, and in extensive wounds its thorough performance inevitably entails additional damage to the collateral circulation.

As a matter of fact, although the American results in World War II at first glance seem to be much worse than the British results in World War I, they are probably better. The British series, as has been pointed out, includes a large number of cases of aneurysm, which are excluded from the American series, and in which, as Elkin[59, 60] and Shumacher have shown, postoperative gangrene is rare.* In World War II the British surgeons have not been encouraged by their own results. At the Cairo Conference, in 1943, Ogilvie stated that in the course of the war he had not seen a single instance of ligation of the popliteal artery which had not been followed by gangrene, and Blackburn, in 1944, in a discussion of surgery in the Field, stated flatly that ligation of the popliteal vessels, in particular, almost invariably leads to amputation above the knee a few days later.

---

* In the combined series of 595 cases of aneurysms reported by these authors there was only one case of gangrene following operation.[59, 190]

THERAPEUTIC MEASURES IN WAR WOUNDS OF THE ARTERIES
LIGATION

From the preceding discussion, it clear that no procedure other than ligation is applicable to the majority of vascular injuries which come under the military surgeon's observation. It is not a procedure of choice. It is a procedure of stern necessity, for the basic purpose of controlling hemorrhage, as well as because of the location, type, size, and character of most battle injuries of the arteries.

From the technical standpoint, with reference to the optimal site for ligation, little discussion is necessary. At the present time, when wound infection is usually a controllable complication and when secondary hemorrhage is, therefore, not the factor of risk which it was in World War I, there seems no justification whatever for the performance of proximal ligation. It may be theoretically desirable to ligate at such a level as to avoid the creation of a blind pouch, but the deliberate effort to do so frequently involves extensive dissection and may still further jeopardize the circulation of the injured limb. The proposal was first made by Leriche and Policard, in 1922, and was reëmphasized by Holman,[87] in 1944, and Rogers, in 1945.

Ligation of the Concomitant Vein.—The chief difference of opinion concerning the technic of ligation has to do with whether or not the concomitant vein should be ligated along with the injured artery. The amount of space devoted in the literature to this discussion seems curiously out of proportion to the value of the procedure, though the manner in which the practice evolved is rather interesting, and has been thoroughly reviewed by Brooks.[25]

Prior to World War I the current opinion seemed to be that the prognosis for survival of a limb after interruption of a major artery was worse if the concomitant vein was injured and had to be ligated simultaneously. Jacobson stated that under these circumstances: "Leave should be gotten at once for amputation." Matas[131] declared that "the danger of peripheral gangrene is always made doubly worse by the simultaneous injury of the accompanying or satellite vein." During World War I, however, a completely opposite point of view developed, with Makins as the originator and chief proponent of the practice for war wounds. Simultaneous ligation of the concomitant vein, in his opinion,[128, 129] is of distinct advantage for two reasons: 1. The capacious main vein affords too ready a channel of exit for the diminished arterial supply, as well as an undesirable reservoir of stagnation. 2. As the result of combined arteriovenous ligation, the smaller amount of blood supplied by the collateral arterial circulation is maintained for a longer time within the limb, and there is, therefore, an improvement in the conditions necessary to preserve its vitality.

Therapeutic venous ligation for venous disease has been known since the time of Hippocrates, but Makins seems first to have proposed it as part of the treatment for acute traumatic arterial lesions. He observed from his experiences in the South African war that a smaller incidence of gangrene followed traumatic arteriovenous fistula when both artery and vein were ligated than

when only the artery was ligated, though, as Brooks[25] pointed out, he did not record the observation until his Bradshaw Lecture, in 1913.[124] Of further interest in this connection is the fact that Makins[125] seemed still unprepared to advocate the procedure in his extensive article on vascular injuries of warfare, published in 1916, and simply stated: "With regard to the question of the danger of simultaneous ligature of the artery and vein, it may be added that this was done in one of the successful cases." In the Hunterian Oration,[126] however, which was delivered in 1917, he advocated the deliberate ligature of the uninjured concomitant vein in cases of arterial occlusion, and at this time,

RESULTS OF LIGATION OF COMPARABLE ARTERIES
WITH AND WITHOUT LIGATION OF CONCOMITANT VEIN
BRITISH WORLD WAR I EXPERIENCE
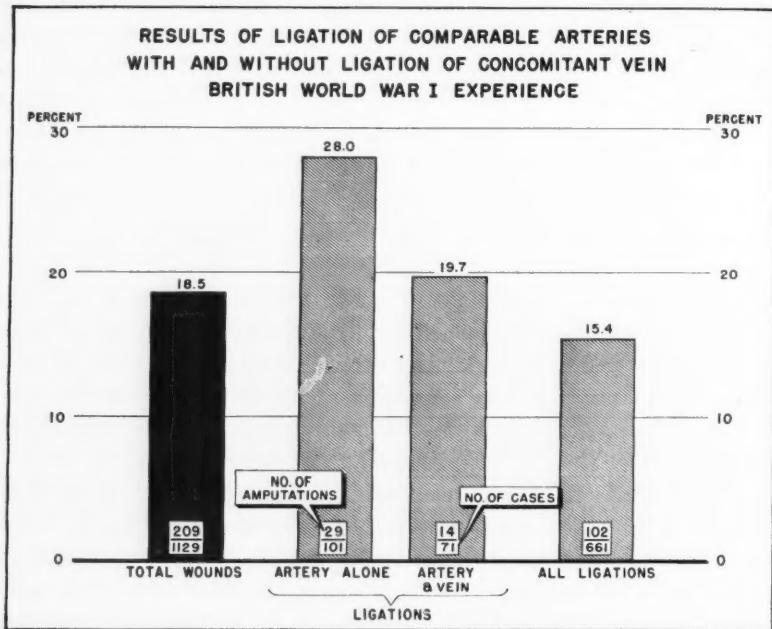
CHART 12.—Results of ligation of comparable arteries with and without ligation of concomitant veins in British casualties in World War I.

as well as in his monograph[128] published after the war, he set forth the evidence on which he based the suggestion and which may be briefly recapitulated as follows:

1. The demonstration in varicose veins of the ease with which a compensatory balance is attained when blood is diverted from the larger channels. 2. The lack of permanent vascular difficulties when the jugular and other large veins are ligated to prevent the diffusion of septic emboli. 3. The possibility of survival after occlusion of the vena cava. 4. His personal experience in arteriovenous fistula to the effect that quadruple ligation and excision are followed by less risk than simple arterial ligation. 5. Von Oppel's[158-161] good results in six cases of occlusion of the popliteal vein in senile gangrene, on the basis of his observation of the occasional good results which follow arteriovenous anastomosis in this condition and which he attributed to control of the venous circulation and the subsequent rise in the blood pressure of the limb.

6. Drummond's experimental demonstration that gangrene follows ligation of the mesenteric artery but not ligation of the mesenteric artery and vein. 7. Van Kend's experimental studies, which showed that local blood pressure was raised in the affected limb when the concomitant vein was ligated subsequent to occlusion of the artery.

The matter was fully discussed at the Inter-Allied Conference of Surgeons, held in Paris in May, 1917, and on the ground of Makins' statistics (Charts 12 and 13) the view was advanced that the concomitant vein should be ligated whenever a major artery was ligated, even if the vein itself was not injured.[47, 93, 127] Some surgeons[46, 135, 136] have accepted this view with some-

RESULTS OF LIGATION OF COMPARABLE ARTERIES
WITH AND WITHOUT LIGATION OF CONCOMITANT VEIN
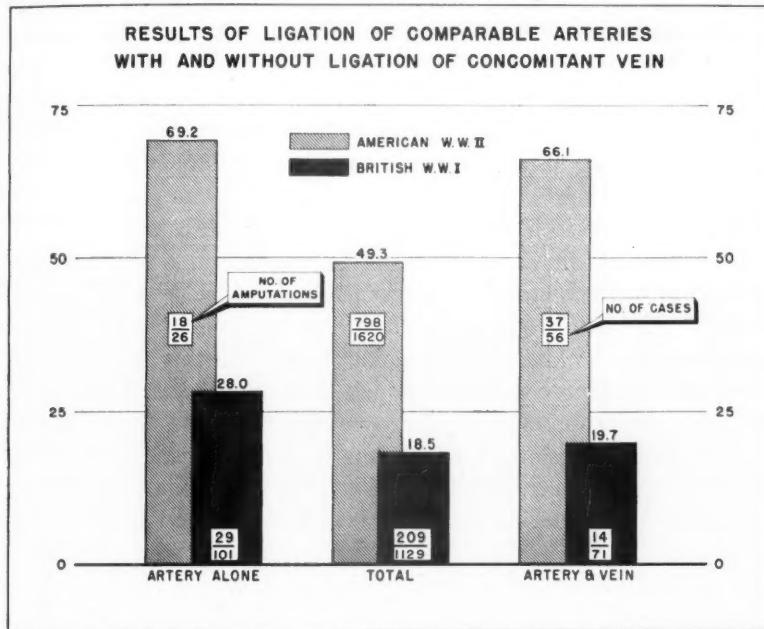
CHART 13.—Results of ligation of comparable arteries with and without ligation of concomitant veins among British casualties in World War I and American casualties in World War II.

thing less than enthusiasm; Maurer, for instance, wrote, in 1921, that concomitant vein ligation is not harmful and might be advantageous, and, in 1939, he had become even less enthusiastic. But the weight of Makins' prestige was so great that for the most part his point of view was accepted without question, and the practice of ligation of the vein became the rule when the artery had to be ligated.[13, 14, 41, 51, 71, 72, 93, 144, 145, 188, 189, 201]

Brooks, in an extensive review of the subject, in 1929, decided on the basis of clinical and experimental evidence[28, 88, 166, 198] that the concomitant vein should be ligated if the popliteal or axillary artery were injured, but that primary venous ligation should not be done if the common femoral artery were ligated, although subsequent ligation of this vein is recommended if signs of impending gangrene become evident. He considered that it made

little difference whether the procedure were performed or omitted if the femoral and brachial arteries were affected. More recently, additional experimental evidence to support this thesis has been published.[117a] Wilson, on the basis of an experimental study published in 1933, stated that his own results did not support the current belief that ligation of the concomitant vein diminished the incidence of gangrene following ligation of the main artery, and added that if the venous ligation were done at a higher level than the arterial ligation, the incidence and extent of tissue death would be increased. This receives indirect support from the observations of Montgomery[148] who found that the per-minute flow of blood to the extremity was reduced further following ligation of the concomitant vein in the extremity in which the artery had been previously ligated. The following year Brooks and his associates[27] published the results of an experimental study of 220 rabbits, 200 of which showed that massive gangrene of the extremity was 14.5 times less frequent after arterial and venous ligation than after arterial ligation alone, from which Brooks and his coworkers concluded that concomitant vein ligation was beneficial. Whereas this may be true for the rabbit, these results do not conform with those observed in man, as will be pointed out below.

While the experimental evidence for and against ligation of the concomitant vein is not always consistent, there seems no doubt, as Wilson has pointed out, that Makins' reasoning in favor of the procedure is not based upon sound physiologic concepts. Makins' often-quoted figures, furthermore, do not seem to warrant the sweeping conclusions which have been drawn from them. For one thing, the proportion of cases of arterial and of venous involvement is not clear, nor is the proportion of aneurysms in the two groups of cases. For another, the difference in the incidence of amputations (Chart 12) between the series in which only arterial ligation was done and the series in which the concomitant vein also was ligated is not statistically significant. Finally, the incidence of amputations in the whole group of wounds of comparable arteries in Makins' collected World War I series is actually less than the incidence of amputations in the series in which the concomitant vein was ligated, though the former series, on the basis of his theories, should provide the larger number (or at least an equal number) of poor results (Chart 12).

Aside from Makins' figures, not a great deal of evidence for or against ligation of the concomitant vein can be found in the literature of World War I. In 1916, which, it is of interest to observe, precedes the published views of Makins on this subject, Sehrt reported the incidence of gangrene in the upper extremity to be 7.8 per cent when the artery alone were ligated and zero per cent when the artery and vein were concomitantly ligated. The corresponding figures for the lower extremity were 20.4 per cent and 9.0 per cent. The numbers of cases are not given. On the basis of this experience, Sehrt concluded that concomitant vein ligation was of distinct value and expressed the belief that "impounding of blood (venous) in the extremity is beneficial." Propping, in 1917, influenced by these observations, attempted to provide experimental evidence to support the opinion that concomitant vein ligation is beneficial and

while the experiment was rather naive be concluded from it that gangrene of a limb after ligation of an artery is the result of an imbalance between the amount of blood entering the extremity and the amount of blood leaving it through the veins. In 1921, Heidrich, on the basis of 698 cases collected from the literature, concluded that the results were better when the concomitant vein was ligated. The incidence of aneurysm in these cases, however, was extremely high, which vitiates their significance. On the other hand, Punin stated, in 1921, on the basis of 64 personal and 1,057 collected cases, that the incidence of gangrene after the combined procedure was no less than when ligation of the vein was omitted. Brooks, in 1929, regarded the procedure not only as of no value but actually contraindicated.

The American experience in World War II (Chart 13) is not extensive. The majority of surgeons did not use concomitant venous ligation routinely, if at all, and the experiences of single surgeons are, therefore, insufficient to determine, one way or the other, the influence of the method on the end-results of vascular injuries. The collected figures seem to indicate that it does not in any way increase the chance of survival of the limb. The difference between the incidence of amputations in the series in which the vein was ligated and in the series in which it was not ligated is not statistically significant. The incidence of amputation in the total wounds of comparable arteries was considerably less than that in the group in which it was known that concomitant vein ligation was done, the difference being statistically significant, though, as was pointed out for the British figures, one would expect the results to be as good, if not much better, when venous ligation was done were the procedure of definitive value.

The conclusion seems legitimate, on the basis of Makins' figures for World War I and the American figures for World War II, that ligation of the concomitant vein furnishes no protection whatsoever against the development of gangrene after acute arterial occlusion and ligation in battle casualties.

SUTURE REPAIR

In addition to ligation, which permanently interrupts the flow of blood through the main channel, arterial wounds have been treated by suture, vein graft, and tube anastomosis. The consensus, at least on theoretic grounds, is that suture repair offers the greatest hope for survival of the limb, but practically, as has been pointed out, reparative measures are seldom applicable to such wounds. The operation should always be considered, however, circumstances permitting, for small lateral wounds, while less often it is a possibility in larger lateral wounds or in incomplete or complete transection.

The theoretic value of suture was recognized during World War I, but it was also realized that the number of cases in which it was possible were extremely few. Sencert wrote, in 1918, that ligature was the method *par excellence* for the arrest of hemorrhage from recent vascular wounds and that the indications for suture were exceptional. Makins stated that suture is the only method which provides ideal results, but added that it is applicable only in the primary stage and only if infection can be avoided. He regarded lateral wounds

of the larger vessels, that is, the carotid, brachial, iliac, femoral and popliteal arteries, as most suited for the method.

Bernheim,[13, 14] who had enthusiastically practised the Carrel method of suture in his civilian work, went to France with an elaborate personal equipment to use it in military surgery. In nearly two years overseas, however, at installations of various levels on several American fronts, he never saw any other surgeon perform it and he himself discontinued it in the few cases in which he attempted it, because of loss of supporting tissue as the result of necessary débridement and because of the unjustifiable amount of time which the operation required. Even in the case in which infection was absent he thought that military circumstances were unpropitious for vascular suture, while "only a foolhardy man," he remarked, "would have essayed suture of arterial or venous trunks in the presence of infections such as were the rule in almost all the injured."

Goodman[70-73] wrote enthusiastically of the advantages of suture, and stated that during a month's stay on the British Front in 1917 he was "enabled to refute the deductions made by the other surgeons present," the deductions being that the risk of gangrene after arterial ligation was sufficient to justify immediate amputation in injuries of the femoral, popliteal, and even the posterior tibial arteries. His personal experience, however, was limited to five cases, in one of which gangrene developed and amputation was required.

Not many other reports concerning the use of immediate suture in acute arterial wounds are available in the literature from World War I.[57, 77, 78, 83, 96, 135, 144, 145, 187, 189, 194, 195] Makins[128, 129] was able to collect only 39 cases. Three patients died, all from infection, and ideal to good results were obtained in about half of the remaining cases, the results being "in no way inferior to ligature," which seems somewhat faint praise. Goodman,[71-73] in addition to his own personal cases, presented a number of collected cases but the large number of aneurysms included in the group makes the figures of little value for comparative purposes. His collection includes a number of cases from the German literature, and there seems no doubt that German surgeons used suture more frequently than either British or American surgeons, though many series, such as that reported by von Haberer,[77, 78] consist chiefly or entirely of aneurysms. Gnilorybov, writing in 1944, stated that during World War I he had had several good results from vascular suture and that he saw no instance of gangrene after its use, in contrast to ligation, after which half of his cases developed gangrene. He did not cite exact figures.

The thorough débridement practiced in World War II, supplemented by chemotherapeutic methods, lessened the fear of infection which presumably discouraged a wide use of vascular suture in World War I. Nevertheless, the number of instances of vascular injuries in which suture was practised continued to be very limited, for the reasons already mentioned, that lateral wounds sufficiently localized to permit suture repair were seldom seen, and that the majority of wounds were accompanied by such widespread destruction of tissue and such loss of arterial substance that end-to-end anastomosis was rarely feasible.

The performance of suture was recorded in only 81 cases in the entire series of 2,471 arterial wounds which indicates the relative infrequency of the practicability of this procedure (Chart 14). Included in the group are three end-to-end anastomoses, of the common femoral, femoral, and popliteal arteries, respectively. Most of the cases were small lateral lacerations, involving a third or less of the circumference of the vessel. It is of interest that only one case in this series was a bayonet wound, and it was accidental; bayonet wounds, because they are cleanly incised and involve no great loss of tissue, would seem to be ideally suited for suture.
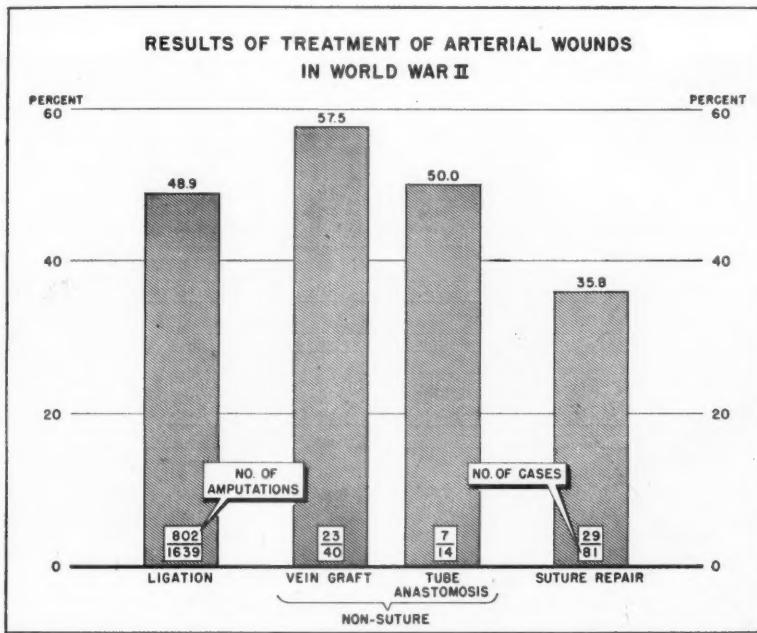
CHART 14.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II, with special reference to the type of arterial repair.

The results of suture in these 81 cases are significantly better than the results of ligation in a larger series of 1,639 cases (Chart 14) and, indeed, are better than the results of any method of treatment employed. Not too much encouragement must be derived from these facts, however, for these cases formed a highly selective group of minimal wounds, without extensive tissue destruction. It would not be possible to duplicate or even to approach these results in the usual run of arterial wounds.

Complications.—The most important immediate complication of vascular suture is hemorrhage. The records are incomplete on this point, but secondary hemorrhage is known to have occurred in two of 24 cases included in the series of 81 cases in which suture was employed. Hemorrhage is usually a late development, occurring six to eight days after operation, by which time a collateral circulation has usually developed, so that ligature can be done with much less

risk to the limb than when it is a primary procedure. Thrombosis and embolism are other immediate but less frequent complications. They were not recorded in any case in this series. Late complications include arterial strictures and aneurysms; at the present writing the follow-up on the cases in this series is incomplete, and no statements can be made concerning their development following arterial suture.

OTHER REPARATIVE METHODS

Because of the extremely destructive weapons used in World War II, arterial wounds were often associated with extensive loss of substance. In the small number of such cases in which arterial ligation did not seem promptly
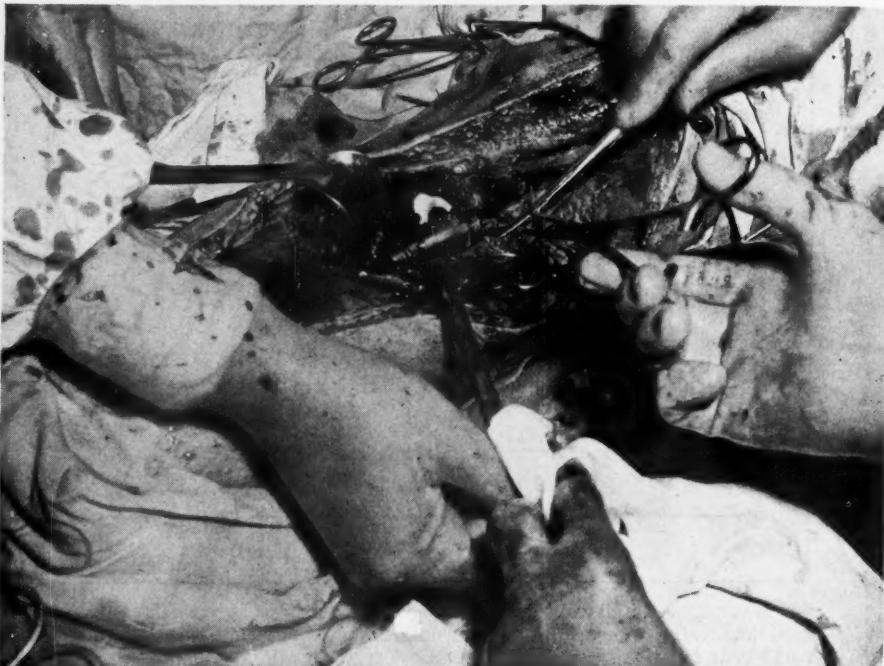
FIG. 1.—Completed nonsuture vein graft anastomosis of popliteal artery. The arterial injury was complicated by a severe compound fracture of the tibia through the knee joint and the dislocated tibial fragments are still attached in the wound.

indicated and in which suture repair was clearly impossible, some method of bridging the gap was considered desirable in order to restore continuity of the artery. Various methods have been suggested and practiced for this purpose, including the use of vein grafts and prosthetic tubes.

Sutured, as opposed to nonsutured, vein grafts had been suggested as a possible method of repair and successfully performed experimentally[70, 76, 150, 151] as well as clinically[117, 207] some years before World War I. Although the procedure does not seem to have been performed for acute arterial occlusion during that war, it was employed for traumatic aneurysms with surprising success.[4, 23, 72, 73, 92, 178, 189, 207, 211] In a series of 47 cases reported by Warthmüller, 40

were considered successful. As Matas[133] emphasized: "There is scarcely any need of grafts" for the type of case in which it was usually employed in light of the development of the technically simpler and highly successful Matas operation. To our knowledge the method was not used for these injuries in any American military installation in World War II. Because of technical, and other difficulties, it has a very limited application, but a few successful clinical cases have been reported during this war, such as the seven cases each by Rehn [176, 177] and Killian, the six (of 10) by Schneider and Batzner, the single case by Murray,[152] and the unstated number by Khenkin. The majority of these cases were done on patients with aneurysms rather than acute arterial wounds.

The principle of nonsuture anastomosis originally developed by Payr, in 1900, thoroughly tested experimentally by Höpfner, in 1903, and successfully applied clinically by Lexer, in 1907, was employed by Blakemore, Stefko, and Lord,[18-21] in 1942 as a method of restoring the blood flow through severed arteries. They used vitallium tubes instead of magnesium alloy tubes which Payr and Höpfner had used, lined them with vein grafts, and tied the cut ends of the artery over the ends of the connecting cannula. Later they modified the method, using two tubes bridged by a vein graft, just as Höpfner had done. Their experimental and clinical results were highly encouraging and they were enthusiastic over the possibilities of the method in military surgery. Of historical interest, also, is the fact that Jeger,[95] in 1913 had advocated the method in military surgery.

During the recently terminated war, the Surgical Consultants Division in the Office of the Surgeon General supplied these vitallium tubes in assorted sizes to the various Theater Consultants, who distributed them to experienced vascular surgeons for trial in Forward Installations. Full details are not yet at hand, but the material analyzed in this communication shows that the double-tube-vein-graft technic (Fig. 1) was employed in 40 cases. The incidence of amputation was somewhat greater than after other methods of repair but the difference is not statistically significant (Chart 14).

A consideration of great importance in military surgery is the ease with which an operation can be performed, and experience indicates that nonsuture anastomosis is neither as simple nor as easy as its proponents, whose experience, of course, is extensive, state it to be. One operation, for instance, performed in an Evacuation Hospital, by a better-than-average surgeon, took three and one-half hours; in the course of the procedure the ligature twice slipped off the tube and had to be tediously reapplied. Complete information is not available as to the number of times this method of anastomosis was attempted but could not be completed, though it is known that this happened five times in one sample consisting of 23 cases. A possible disadvantage of the method in cases in which it cannot be completed is that additional arterial substance may be destroyed in the course of the attempted application of the tube (Fig. 2).

Bridging of the arterial gap by intubation to provide for temporary maintenance of the blood flow is a fairly old principle. In 1915, Tuffier, who rea-

soned from his experiences with the use of silver tubes in performing direct blood transfusion, proposed the use of these tubes for bridging arterial defects and was successful in a number of cases. Makins, in 1922, reported 12 cases treated by this method, four of which, however, were not acute lesions. One patient died of sepsis and one of gas gangrene, but the results were good in the remaining cases. Makins also mentioned Cowell's case, in which, following
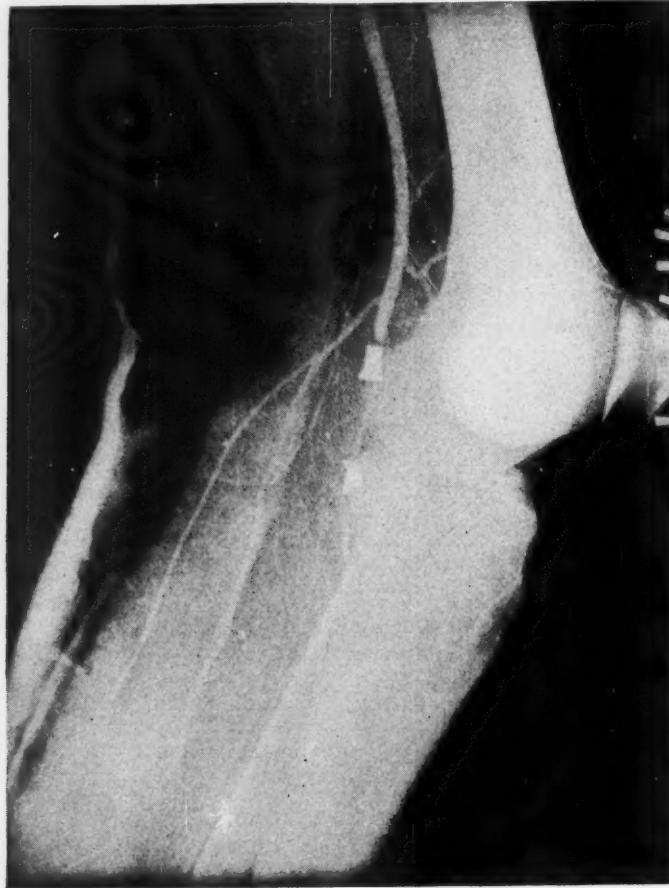

Fig. 2.—Arteriograph 1.5 weeks after nonsuture anastomosis of popliteal artery, showing complete obstruction of the anastomosis. This case illustrates the possible damage to important arterial branches if too much of the artery is used in the anastomosis. The limb might not have survived if the branch to the gastrocnemius soleus group of muscles had not been spared. (Operation by Harbison and Simeone.)

ligature of a completely divided femoral artery, signs of gangrene ensued but the limb was saved by removal of the ligatures and the application of a Tuffier tube. The generally favorable opinion of the procedure is reflected in the writings of a number of authors during that period.[24, 52, 72, 92, 128, 129, 201, 202]

To accomplish the same objective as the silver tubes used in World War I,

glass tubes were suggested early in World War II.[134] While it is known that they were used by British and Canadian surgeons during this war, no details concerning their experience are available at this writing. The potential clinical value of the method was indicated by the successful experience of Murray and Jones in their experimental studies with heparin on dogs.

Plastic tubes were also suggested and employed in a similar manner as glass tubes. In the material analyzed there were 14 cases in which this method of repair was employed. Although the results obtained in this group of cases are not much different from those following other forms of repair, the series is
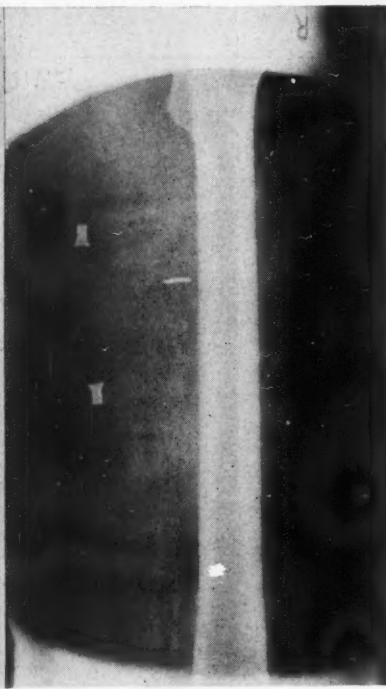
FIG. 3   FIG. 4

FIG. 3.—Arteriograph 3.5 weeks after nonsuture anastomosis of superficial femoral artery, showing patency of the anastomosis and no evidence of undue ballooning of the vein segment. Clinically, the patient showed excellent peripheral circulation. (Initial operation at 8th Evacuation Hospital.)

FIG. 4.—Roentgenograph after nonsuture anastomosis of superficial femoral artery. The extent of the defect which may be bridged, as shown by the positions of the vitallium tubes in this instance, is often considerable. The repair was successful.

obviously too small to permit definite conclusions (Chart 14). Plastic prostheses have certain advantages over other prosthetic devices used in the repair of arterial defects. They are apparently well tolerated by the tissues, and since they can be altered in size and shape to fit the necessities of the special case, merely by soaking the basic material in warm water, a supply of tubes of various sizes need not be kept on hand, as is necessary when vitallium or glass

tubes are used. The technic of repair by this method is also simpler than when vitallium tubes are used. On the other hand, the possibility of thrombosis is probably greater than that following the use of vein grafts (Fig. 3).

The object of tube anastomosis in arterial injuries is the maintenance of the circulation of the injured limb while a collateral circulation is developing. If this objective can be achieved, the later gradual occlusion of the tube, with cutting off of the circulation in the main vascular channel, will have a much less deleterious effect than if these processes had occurred abruptly. To achieve the desired result, however, the patients must be seen early, and the irreducible time-lag, discussed elsewhere in this communication, makes this impossible in the majority of cases.
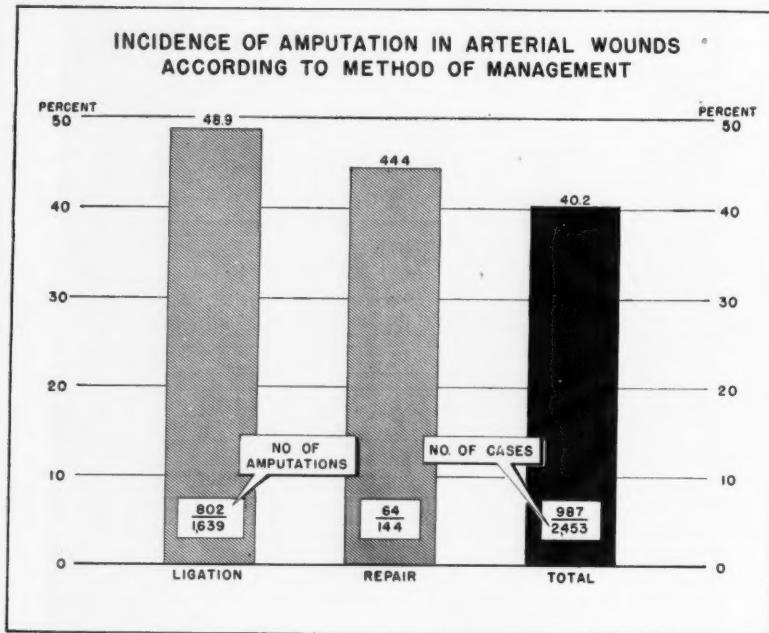
CHART 15.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II.

A broader experience will be necessary to determine the usefulness of all nonsuture and other methods of arterial repair in war wounds. Individual cases (Fig. 3) can be cited in which it may be said that one or another method may have been responsible for the saving of all or part of a limb, but the overall figures (Chart 15) do not show sufficiently significant differences to warrant definitive conclusions. In all fairness, however, it must be said that the cases selected for trial were all cases in which suture repair was not feasible because of the size of the defect (Fig. 4) and in which the prognosis was grave, and the proportion of critical vessels involved was higher than in the series in which ligation was done.

CONSERVATIVE (NONSURGICAL) THERAPY

For the sake of completeness a few words should be said about conservative (nonsurgical) therapy, which has been suggested for a small group of selected vascular injuries, in which it is hoped that uncomplicated healing will occur, or, if it does not, that aneurysm formation will take place. The almost negligible incidence of loss of limb after excision of aneurysms prompts the rather paradoxical statement that the best safeguard for the survival of a limb is to permit an acute arterial wound to develop into an aneurysm. The great majority of aneurysms occur accidentally, however, rather than as the result of deliberate surgical inaction. The principal objection to conservative therapy in battle injuries of the arteries is that it usually implies the omission of débridement, which is so essential a phase of the management of all war wounds that exceptions to its routine performance must be made with the greatest caution. Conservative therapy was advocated as a deliberate policy by some British surgeons[30, 61] at the Congress of C. M. F. Army Surgeons held in Rome in February, 1945, but few arterial wounds among American troops were deliberately treated by this plan. Three cases, in all of which the results were good, were treated conservatively by Sandzen and Evans in a series of 89 vascular wounds, 64 of which involved major arteries, and Rose, Hess and Welch treated eight of 100 cases in this way, also with good results. In four of the eight cases the wounded vessels were exposed during débridement, and in the other four instances, in each of which the popliteal artery was involved, they were not exposed at all.

The selection of cases for conservative management requires expert surgical judgment, as well as a good deal of courage. Generally speaking, it is best to explore even trivial wounds, with the idea of performing remedial or reparative surgery if there is evidence of complete interruption of the circulation.

SUPPLEMENTAL THERAPEUTIC MEASURES

Anticoagulant Therapy.—Anticoagulant therapy, in spite of its value in selected cases in civilian surgery, has an extremely limited application in military vascular surgery. Its use immediately after wounding, as has already been pointed out, is impractical because its safe application demands that it can be used only in a hospital, where close clinical observation and repeated laboratory studies are possible. Mere arrival at the hospital, however, does not mean that anticoagulant measures can immediately be applied. They are not safe even then until (1) the patient has been properly examined and it has been determined that the injury is limited to the vascular wound, and until (2) the operation has been concluded. It may be theoretically possible to employ heparin or some similar agent before operation and to control the clotting time during the procedure, but it is doubtful whether even in a civilian hospital this would be a practical plan. In a military installation it would be neither practical nor safe.

In the last analysis, the time-lag between wounding and the safe period for the institution of anticoagulation therapy is likely to be so long that this measure is no longer useful when it could safely be applied: Thrombosis would

already have occurred and the distal portion of the extremity would have been deprived of blood for too long a period for the pathologic changes which occur in the absence of circulation to be reversible. On the other hand, in the individual cases of battle wounds in which anticoagulant therapy is indicated and conditions permit continuous, careful observation, with adequate laboratory checks, the method has a definite field of usefulness and should be employed. Data are not available as to how often anticoagulant therapy was used in vascular wounds by American surgeons in World War II, although it is known that it was employed only rarely. In one sample of 12 cases in which it was instituted (in some it was administered in Pitkin's menstruum)[118] as early as was considered feasible under the military conditions and in which careful studies were made no significant advantages were observed from its use.[192]

Sympathetic Block and Sympathectomy.—Considerable clinical and experimental evidence exists to show that vasospasm is a natural response to those forms of trauma which directly or indirectly affect vascular structures. Spasm of the major arteries in wounds of the extremities was recognized in World War I,[48, 55, 103, 105, 113, 136, 137, 189, 196, 205, 206] and has since been observed and studied clinically and experimentally.[11, 35, 37, 38, 66, 68, 79, 84, 90, 112,113, 116, 121, 147, 155, 172, 197, 209] The degree of vasospasm varies considerably, ranging from localized constriction with consequent minimal ischemia to a more extensive and generalized involvement, especially of the collateral circulation, with consequent ischemia of a degree sufficient to produce actual gangrene. Rational therapy in such cases is based upon an attempt to counteract vasospasm and to produce maximum vasodilatation in the involved extremity. Since the disturbance is apparently due to a vasomotor reflex initiated in the traumatized tissues, and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses by means of sympathetic block or sympathectomy has been suggested and practiced by numerous observers.[16, 45, 66, 68, 75, 99, 100, 110, 113, 130, 155, 168]

Interruption of the sympathetic impulses usually by chemical means (procain hydrochloride), was widely practiced by American surgeons in World War II, but in the material available for analysis it was possible to determine in only 278 cases that the procedure had been performed or had been omitted. The results of the analysis (Chart 16) provide no substantial evidence that this method was of any value. The incidence of amputation in the group in which sympathetic block was performed is only slightly less than the incidence for the group as a whole, while the incidence in the cases in which ganglionectomy was done is greater than for the entire series.

These figures might seem to suggest that sympathectomy is a valueless procedure, but familiarity with the clinical material permits a different, and more accurate, interpretation: As a rule, sympathectomy was used only as a last resort, when it had already become apparent that the limb would not survive, while sympathetic block was more frequently instituted as part of the immediate postoperative routine, being continued until the outcome in respect to survival or death of the limb had become obvious. In the light of this knowl-

edge the apparently poor results of sympathectomy and the better results of sympathetic block are more readily understood.

The difficulties of evaluating such procedures as these on a purely statistical basis should also be emphasized: In the first place, the effective performance of the block is frequently open to doubt, and in the second place, proper objective methods are lacking to determine the efficacy of the procedure, while suitable controls upon which to base an evaluation of results are also lacking. The survival or death of the limb, which at first glance might seem to be a critically objective test, actually is not: It does not permit a clear decision as to whether the therapeutic measures employed in a given case have influenced the results, and it can serve as a criterion only when sufficiently large numbers of cases are available for statistical evaluation.
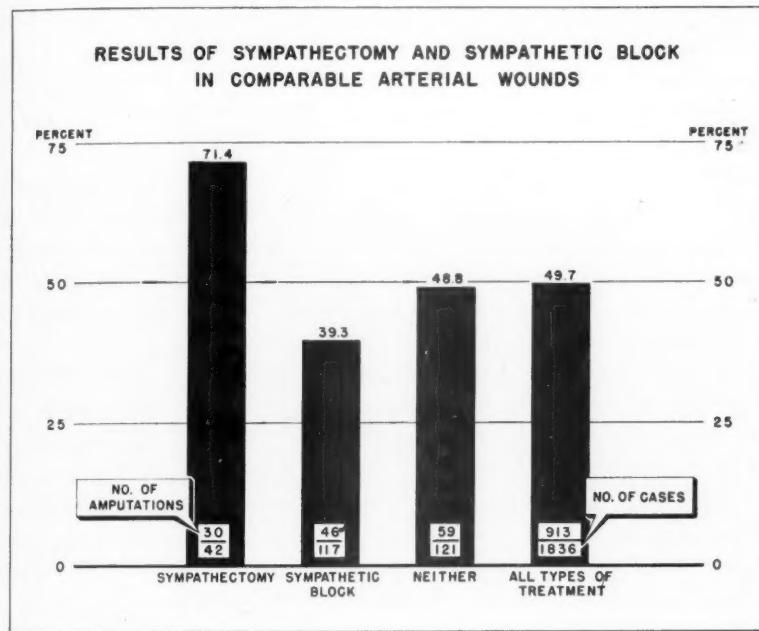
CHART 16.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II, with special reference to sympathectomy and sympathetic block.

Perhaps the chief difficulty in critical evaluation of this method is the fact that in the great majority of arterial injuries the question of the viability of the part has been established at the time of wounding, and the margin within which improvement can be demonstrated is, therefore, so small that great numbers of cases are required to establish on a statistical basis the efficacy of any single procedure.

In spite of the lack of statistical data, however, there is considerable evidence in favor of sympathectomy and sympathetic block from personal experience and from the experiences of other surgeons. Cases can be cited in which moderate degrees of tense swelling and muscle pain characteristic of muscular

ischemia have regressed and in which the temperature of the limb has improved following ganglionectomy. In fact, the statement is perfectly fair that the experiences of most American surgeons working in the forward areas are to the effect that sympathectomy and sympathetic block were useful and beneficial procedures, regardless of inconclusive statistical evidence to prove the point.

Cohen[38] has taken exception to the theory that arterial spasm is influenced by local or distant autonomic reflexes, on the ground that it is myogenic in origin. In addition, he has cited evidence suggesting that blocking of the vasomotor control of the wounded limb is dangerous, because, he concludes, vasodilatation in the skin is not accompanied by vasodilatation in the muscles, and harm is done by diverting the blood from the muscles into the skin. He, therefore, deprecates the use of sympathetic block or sympathectomy as a therapeutic measure to combat traumatic vasospasm associated with direct injury. Curiously, however, he advocates the use of sympathectomy to control vasospasm associated with a crushing injury or following the prolonged application of a tourniquet, on the ground that the vasospasm observed in these types of vascular injuries is of a reflex nature. There are two obvious inconsistencies in Cohen's reasoning. The first is his assumption that vasospasm can be initiated reflexly by one type of trauma and not by another, even though the end-results of both, insofar as tissue damage, as well as ischemia and its consequences, is concerned, are the same. The second is his assumption that sympathetic block or sympathectomy can be both injurious and beneficial for vasospasm initiated by different types of trauma.

Fasciotomy.—The tense, hard swelling of the muscles of the forearm and leg frequently observed after complete obstruction to the blood supply of those parts has been related to rigor mortis (Fig. 5). Actually the two conditions are not identical, since in ischemic swelling the muscles appear to be contained under considerable pressure by the enveloping fascia. Following interruption of the main arterial supply to the muscles of the affected limb, a vicious circle promptly develops, in which the impairment of the capillary circulation is increased by the swelling of the muscular tissue and the pressure of the enveloping fascia, while the swelling and pressure are themselves increased by the increasing impairment of the capillary circulation. Eventually a stage is reached at which circulation ceases entirely.

On the basis of these assumptions, fasciotomy has been recommended not only for cases in which ischemic swelling has already developed but also for incipient cases in which progression seems likely. Longitudinal incisions are used in both upper and lower extremities. In the leg the incision is made posteromedially to decompress the gastrocnemius-soleus group of muscles and anterolaterally to decompress the anterior tibial compartment. In the forearm the incision is made on the volar aspect.

Fasciotomy is open to criticism on the ground that the incision may destroy the collateral circulation from the skin and may further compromise the regional circulation by introducing the risk of infection. On more theoretical grounds, however, these objections are superseded by the consideration that

fasciotomy may permit the reestablishment of circulation through the ischemic muscle.

Although certain British surgeons[30, 36] in the Mediterranean Theater were enthusiastic advocates of fasciotomy, American surgeons in this area were much less favorably impressed by it. In the limited number of cases in which it is known to have been used the results were occasionally good, though they were poor in the majority of the wounds of the popliteal artery in which it was employed.

Refrigeration.—The concept of reducing the metabolism of an injured part by cooling, to make metabolic activity commensurate with such circulation as

FIG. 5.—Tense swelling of muscles of calf, without significant subcutaneous edema, 12 hours after transection of popliteal artery. Fasciotomy may aid the capillary circulation in this type of case.

is available in it, is theoretically sound.[22, 64] On the other hand, the wisdom of actual refrigeration is still open to question for any purposes except to control infection and diminish lymphatic absorption from an infected limb prior to amputation, or to permit amputation without anesthesia in an aged and debilitated subject.[50, 107, 179] Moreover, several carefully controlled studies have clearly demonstrated that after refrigeration healing progresses less satisfactorily,[107, 108] wound infection tends to progress more rapidly and to be more serious,[26, 31] and the nerves in the cooled area are liable to damage.[109]

Certain advocates of refrigeration[5-9, 44, 123, 170, 171] have proposed the use of refrigeration under combat conditions, "particularly for military emergencies

with a sudden rush of battle casualties," and have charged the failure to use it widely under such circumstances to "inaction" on the part of the military services and "official negativism" on the part of the Committee on Medical Research.[7-9] The enthusiasm of the advocates of the method, while characteristic, clearly reflects an ignorance of the therapeutic limitations imposed by military exigencies. Aside from any other consideration, the chief argument against an extensive trial of refrigeration in military vascular surgery is the utter impracticability of attempting to apply it under battle conditions.

Amputation was required in three personally observed cases in which refrigeration was used in wounds of the femoral and popliteal arteries, which is in accord with the experiences of Auster, Snyder, and Ottoway and Foote. No evidence, in fact, exists that this method has saved limbs after wounds of the major arteries, and it is to be feared, as has already been indicated, that its prolonged use can lead to damage of the tissues which it is expected to preserve.

While the application of cold to the limb is not considered wise, the application of heat directly is equally unwise. The body is warmly covered, with the exception of the limb itself, which is left uncovered and is exposed to room temperature, with the object of minimizing local tissue metabolism.

Oxygen Therapy.—Since lack of available oxygen is one of the factors responsible for death of tissue after vascular occlusion, oxygen inhalation has been suggested as a method of supplying the lack. An increase in the oxygen saturation of the blood is easily effected by this means when oxygenation is impaired by intrathoracic wounds or similar causes. Under normal respiratory conditions, however, an increase in the partial pressure of oxygen in the inspired air has little effect upon the oxygen content of the blood. The slight increase (15 per cent) achieved by inhalations is made possible by an increase in the amount of oxygen dissolved in the plasma. Whether or not this increase results in a sufficient increase in the oxygen gradient between the capillary blood and the rest of the tissues to affect the outcome in arterial injuries is not known. Oxygen inhalation might be desirable, but it is doubtful that the slight benefits which might be achieved compensate for the difficulties inherent in the use of the method under combat conditions. It would seem more important to devote the effort to the correction of oligemia and anemia, with the object of improving the oxygen-carrying capacity of the circulating blood.

Posture.—The position of an extremity in which the blood supply is embarrassed as the result of disease or injury has long been regarded of some importance. In such conditions, and particularly in acute occlusions of the main arterial channels, the blood flow to the part is impeded and must be maintained through the collateral circulation. Elevation of the extremity above the heart level accentuates the ischemia by forcing the blood flow to overcome the amount of gravity pull created by the degree of elevation above the level of the heart. For this reason it appears more rational to maintain the extremity at heart level, or preferably in a slightly dependent position, even if a moderate degree of edema appears to be the result. The experience of American surgeons has, in general, confirmed the desirability of this procedure.

Cohen,[38] on the other hand, disagrees with both the rationale and the application of this principle. He advocates elevation of the limb, basing his recommendation on the belief that this "does not empty the arterial tree and cause capillary anoxia," and that it diminishes venous pressure and increases lymph flow, with consequent prevention of edema which would compress the capillaries. The available evidence on these controversial points is not sufficiently impressive, in our opinon, to permit definitive conclusions.

Physiologic rest of the injured limb is essential, both to reduce to a minimum the nutritional needs of the tissues and to limit infection and absorption of toxic by-products. This is best achieved by immobilization in a well-padded plaster of paris encasement, the upper half of which has been removed.

COMPLICATIONS AND SEQUELAE

As emphasized previously, this report has been concerned essentially with a consideration of acute or fresh wounds of the arteries. The local sequels of certain types of arterial or combined arterial and venous injuries, such as arterial hematoma ("pulsating hematoma"), traumatic false aneurysms, varicose aneurysms and aneurysmal varix, have been purposely omitted. In general, operative management of these lesions may be deferred for several months and is, in fact, preferable in order to permit the development of an adequate collateral circulation. Occasionally, however, certain complications arise necessitating operation, which may be urgent. These include hemorrhage, rapid expansion of the tumor, pressure upon contiguous structures such as nerves and blood vessels, infection and local pain. These complications are more liable to occur in arterial or "pulsating" hematoma and traumatic false aneurysms and are rarely observed in arteriovenous aneurysms. Occasionally excision of an arteriovenous aneurysm is indicated because of actual or impending gangrene in the periphery. Further considerations of these complications and their management may be found in a number of recent publications.[12, 32, 34, 40, 42, 43, 58, 66-68, 80, 81, 86, 98, 100, 138, 149, 190]

Other complications or sequelae include secondary hemorrhage, infection, vascular insufficiency, Volkmann's contracture, and causalgia. Secondary hemorrhage following vascular wounds was a common and greatly dreaded complication in previous wars.[2, 51, 56, 74, 82, 125, 132, 133, 154, 168, 184, 188, 189, 200-202, 208] During two years (1916–1918) of World War I, Waugh observed that among 10,000 patients with wounds involving long bones 14 per cent developed secondary hemorrhage in the first year and 9 per cent in the second year. He attributed the reduction during the latter period to "improved arrangements for adequate early excision of wounds." Tuffier,[202] in commenting upon secondary hemorrhage from arterial wounds during that period, stated that the incidence diminished "in proportion to the diminution of infected wounds." During World War II this complication has been observed relatively infrequently, as demonstrated by Freeman,[65] and by Warren. The former recorded its occurrence in only 23 (1.06 per cent) cases, 15 of which were associated with major blood vessels, among a series of 2,168 gunshot wounds. In over 9,500 casualties recorded by Warren, there were only 13 cases of secondary

hemorrhage severe enough to require operative interference or to cause death. The very low incidence and comparative insignificance of this complication in World War II is believed to be related to the lessened incidence of infection, which, in turn, is related to the performance of more adequate initial wound surgery.

Amputation after arterial wounds is done for one of two reasons, gangrene or infection. The so-called "toxic absorption," presumably the result of autolysis of muscle in the ischemic limb, for which amputation is done to relieve systemic manifestations, is probably of infectious origin in most instances. Table II shows the causes for amputations in 189 cases in this material in which amputations were done for vascular injury. The numbers, while small, suggest the relative frequency of all important complications after wounds of the arteries. When clostridial myositis and other infections are combined, it will be observed that nearly a fifth of the amputations were done for these two complications, whereas ischemia as a direct consequence of the vascular wound was the essential cause for the amputation in the remainder. In contrast with this experience, Turokets in an analysis of 49 cases of wounds of blood vessels sustained in the Finnish campaign of 1939 found that in the 12 cases requiring amputation only two were for ischemic gangrene whereas ten were for gas gangrene or infection.

Causalgia or causalgia-like conditions occasionally develop following arterial injuries and were observed during World War I, [51, 111, 112, 114] although a few reports[53, 139, 140, 191] on World War II experience have appeared in the literature. Accurate figures indicating the incidence of the condition after arterial wounds in World War II are not available. However, the complication is believed to be infrequent. This is supported by the observations of Mayfield and Ulmer, whose series of 75 cases included no patient with associated major vascular injury. In one group of 35 patients reported from a vascular center in the Zone of the Interior, causalgia was recorded only once. In another group of 77 patients, 17 cases of causalgia were observed. These figures are weighted, however, in that they include only the cases in which complications required the reference of the patients to vascular centers and do not include uncomplicated cases. It is of interest to observe in this group that the incidence of causalgia was much higher when nerve injuries were associated with the vascular injuries than when they were absent, the respective figures being 30 and 6.9 per cent. The great majority of these patients responded well to sympathetic block and sympathectomy.

After interruption of a major artery of a limb, the circulation may be so seriously impaired as to necessitate amputation of the limb; or it may be entirely adequate, so that a few weeks after the injury, there may be no detectable abnormality. Between these extremes are degrees of circulatory insufficiency which vary from symptoms brought on only after exertion to discomfort even at rest. Clinical manifestations consist of color changes, intermittent claudication, and sometimes, in the more severe cases, partial paralysis. Similar observations were made during World War I, and have been described by a num-

ber of authors,[33, 111-114, 116, 128, 144, 145, 188, 189, 201, 202] No accurate data are now available to permit statements as to the exact incidence of the condition. In one sample of 88 cases, however, vascular insufficiency severe enough to be manifested clinically was observed in 68 per cent. Two of the patients had had early sympathectomy and in 49 the operation was done late, with definite improvement in all but one. The concept of sympathectomy in these cases was developed by Leriche during the last war and this procedure apparently provided the best results that were reported in the management of this condition. Contractures involving the forearm and hand and less frequently the leg and foot constitute one of the most crippling sequels of acute ischemia consequent to arterial wounds. The conditions apparently develop as a result of severe ischemia just short of causing actual gangrene. It would appear to be essentially similar to Volkmann's ischemic contracture, which in civilian practice is usually observed in injuries associated with fractures.[2, 62, 75, 89, 164, 169] While it has not been possible to ascertain the incidence of this complication following arterial wounds, its occurrence has been relatively infrequent. In one sample of 35 cases of arterial injuries from a Vascular Center in this country there were four cases with contractures. In another sample of 77 cases from another Vascular Center there were 20 cases with contractures. While these proportions seem high it should be realized that these series of vascular cases are weighted by the fact that the Centers attract the complicated cases. The management of this condition has not been very satisfactory. Although efforts have been made to improve the circulation, including the use of sympathectomy, in general the results have been, at best, only moderately good. Other attacks upon the problem have taken the directions of orthopedic plastic operations and physiotherapy measures in the attempt to make the best use of whatever functioning muscle tissue remains.

BIBLIOGRAPHY

[1] Aird, Ian: A Review of Recent Russian Studies of Gunshot Wounds of the Thigh. Bull. War Med., **4**, 619–620, 1944.

[2] Alamartine, H.: Les plaies artérielles sans hémorragie externe (hématomes diffus, fistules artérioso-veineuses, anéurysmes traumatiques) et leur traitement chirurgical. Lyon Chirurg., **14**, 687–708, 1917.

[3] Albert, M., and Mitchell, W. R. D.: Volkmann's Ischemia of the Leg. Lancet, **244**, 519, 1943.

[4] Alessandri, Roberto: Chirurgia del cuore e Dei Grossi Vasi. Cinquième Congrès de la Société Internationale de Chirurgie, Paris, 19–23 Juillet 1920. pp. 139–241, M. Hayez, Brussels, 1921.

[5] Allen, F. M.: The Resistance of Peripheral Tissues to Asphyxia at Various Temperatures. Surg., Gynec. & Obst., **67**, 746–751, 1938.

[6] Allen, F. M.: Reduced Temperatures in Surgery. I. Surgery of Limbs. Am. J. Surg., **52**, 225–237, 1941.

[7] Allen, Frederick M.: Treatment of Surgical Shock and Embolism. J. Internat. Coll. Surg., 7, 23–425. Nov.-Dec., 1944.

[8] Allen, Frederick M.: Broader Aspects of Refrigeration Anesthesia. Anes. & Analg., **24**, 51–65, 1945.

[9] Allen, Frederick M.: Refrigeration in General Surgery of Limbs. Am. J. Surg., **68**, 170–184, 1945.

[10] Auster, L. S.: Combat Injuries in the South Pacific. U. S. Nav. M. Bull., **42**, 1009–1018, 1944.

[11] Barnes, J. M., and Trueta, J.: Arterial Spasm: An Experimental Study. Brit. J. Surg., **30**, 74–79, 1942.

[12] Beck, William C.: "Pulsating" Hematoma (False Aneurysm). War Med., **4**, 502–507, 1943.

[13] Bernheim, Bertram M.: Blood Vessel Surgery in the War. Surg., Gynec. & Obst., **30**, 564–567, 1920.

[14] Bernheim, Bertram M.: Management of Vascular Injuries. S. Clin. North America, **22**, 1417–1426, 1942.

[15] Bier: Chirurgie der Gefässe: Aneurysmen Kriegschirurgische, Heft der Beiträge zur klinischen Chirurgie. **96**, 556–560, 1915, Tubingen.

[16] Bisgard, J. Dewey: Traumatic Neurocirculatory Disorders of the Extremities. Am. J. Surg., **67**, 201–216, 1945.

[17] Blackburn, Guy: Surgery in the Field. Lancet, **1**, 361–365, 1944.

[18] Blakemore, A. H., Lord, J. W., Jr., and Stefko, Paul L.: The Severed Primary Artery in the War Wounded: A Nonsuture Method of Bridging Arterial Defects. Surgery, **12**, 488–508, 1942.

[19] Blakemore, A. H., Lord, J. W., Jr., and Stefko, P. L.: Restoration of Blood Flow in Damaged Arteries: Further Studies on a Nonsuture Method of Blood Vessel Anastomosis. ANNALS OF SURGERY, **117**, 481–497, 1943.

[20] Blakemore, Arthur H., and Lord, Jere W.: A Nonsuture Method of Blood Vessel Anastomosis: Review of Experimental Study. Report of Clinical Cases. ANNALS OF SURGERY, **121**, 435–451, 1945.

[21] Blakemore, Arthur H., and Lord, Jere W.: A Nonsuture Method of Blood Vessel Anastomosis: Experimental and Clinical Study. J. A. M. A., **127**, 685–691; *idem, ibid.*: 748–753, 1945.

[22] Blalock, Alfred: Effects of Lowering Temperature of an Injured Extremity to which a Tourniquet has been Applied. Arch. Surg., **46**, 167–170, 1943.

[23] Von Bonin, G.: Aneurysmen durch Schussverletzungen und ihre Behandlung. Beitr. z. klin. Chir., **97**, 146–176, 1915.

[24] Bowlby, Anthony, and Wallace, Cuthbert: The Development of British Surgery at the Front. Brit. Med. J., **1**., 705–721. June 2, 1917.

[25] Brooks, Barney: Surgical Application of Therapeutic Venous Obstruction. Arch. Surg., **19**, 1–23, 1929.

[26] Brooks, Barney, and Duncan, George: The Influence of Temperature on Wounds. ANNALS OF SURGERY, **114**, 1069, 1941.

[27] Brooks, Barney, Johnson, George S., and Kirtley, James A., Jr.: I. Simultaneous Vein Ligation: An Experimental Study of the Effect of Ligation of the Concomitant Vein on the Incidence of Gangrene following Arterial Obstruction. Surg., Gynec. & Obst., **59**, 496–500, 1934.

[28] Brooks, Barney, and Martin, Kirby A.: Simultaneous Ligation of Vein and Artery: An Experimental Study. J. A. M. A., **80**, 1678–1681, 1923.

[29] Brooks (1929): Cited by Franz.[63]

[30] Brown, J. J. Mason: A Plea for Conservatism in the Primary Surgery of Wounds of the Main Arteries of the Limbs. Proc. Cong. C. M. F. Army Surgeons, Rome, 12–19 February 1945; pp. 103–106. Also discussions by Major Robb and Major Cleland.

[31] Bruneau, Jacques, and Heinbecker, Peter: Effects of Cooling on Experimentally Infected Tissues. ANNALS OF SURGERY, **120**, 716–726, 1944.

[32] Bumm, E.: Das pulsierende Hämatom (Aneurysma spurium) als Kriegsverletzungsfolge. Med. Klin., **36**, 428–431, 1940.

[33] Burrows, Harold: Paralysis Following Arterial Injuries. Brit. M. J., **1**, 199–203, 1918.

[34] Carerji, L.: Ematomi pulsanti e aneurismi traumatici da ferite di guerra (Contributo clinico e istologico). Arch. Ital. di Chir., **50**, 244–302, 1939.

35 Clark, C. W.: Traumatic Arterial Spasm. Brit. M. J., **2**, 167, 1943.

36 Clark, Ruscoe: Forward Surgery of Injuries to Major Blood Vessels. Proc. Cong. C. M. F. Army Surgeons, Rome, 12-19 February 1945, pp. 107-111.

37 Cohen, Sol M.: Traumatic Arterial Spasm. Guy's Hosp. Rep., **90**, 201-216, 1940-1941.

38 Cohen, Sol M.: Traumatic Arterial Spasm. Lancet, **1**, 1-6, 1944.

39 Cole, J. P., and Neel, H. B.: Injuries of the Extremities in Amphibious Warfare. Surg., Gynec. & Obst., **79**, 573-583, 1944.

40 Conway, Herbert, and Plain, George: Pulsating Hematoma, False Aneurysm and Arteriovenous Fistula due to War Injuries. In Press.

41 Cowell, E. M.: Simultaneous Ligature of Arterial and Venous Trunks in War Surgery. Brit. M. J., **1**, 577-578, 1917.

42 Crile, G.: Naval Casualties in a Base Hospital in the South Pacific. Arch. Surg., **48**, 305-314, 1944.

43 Crile, George, Jr.: Management of Injuries of Major Blood Vessels. U. S. Nav. M. Bull., **45**, 1076-1080, 1945.

44 Crossman, L. W.: Ruggiero, W. F.; Hurley, V., and Allen, F. M.: Reduced Temperatures in Surgery. Arch. Surg., **44**, 139, 1942.

45 DeBakey, Michael: Traumatic Vasospasm. Bull. U. S. Army M. Dept. No. 73, p. 23, February, 1944.

46 Decker, P.: Emergency Hemostasis in War Surgery. Helvet. med. acta, **8**, 3, April, 1941.

47 Depage, A.: Blessures des Vaisseaux. Comptes Rendus de la Conférence Chirurgicale Interallié pour l'étude des plaies de guerre, 5° Séance, 16 May 1917. Arch. de Méd. et de Phar. mil., **68**, 324-328, 1917.

48 Desplats, R., and Buquet, A.: De l'oblitération traumatique des artères des membres; l'ischemie nerveuse des blesses de guerre. Bull. et mém. Soc. de chir. de Paris, **43**, 1959, 1917.

49 DeTákáts, Géza: Vascular Surgery in the War. War Med., **3**, 291-296, 1943.

50 DeTákáts, Géza, and Miller, D. S.: Use of Direct Heat and Indirect Heat to Increase Blood Flow to the Extremities. War Med., **2**, 429-436, 1942.

51 Donati, M.: Ferite dei vasi sanguigni. Boll. di Soc. Med. Chir. di Modena, **19**, 15-18, 1917.

52 Donati, M.: Ferite dei vasi sanguigni degli arti. Chir. d. organ. d. mov., Bologna, **1**, 191, 1917.

53 Doupe, J., Cullen, C. H., and Chance, G. Q.: Posttraumatic Pain and the Causalgic Syndrome. J. Neurol., Neurosurg. & Psychiat., **7**, 33-48, 1944.

54 Drummond, Hamilton: Quoted by Makins.[128]

55 Ducastaing, R.: Note sur quatre cas de stupeur artérielle traumatique. Bull. et Mém. de Soc. de Chirurgiens de Paris, **45**, 604-611, 1919.

56 Duval, Pierre: Statistique opératoire d'un sector chirurgical (X° région, sector Fougeres-Granville-Dinard) du 1er Janvier 1915 et 1er Mar. 1916. Bull. et mém. de Soc. de chirurgiens de Paris, **42**, 893-897, 1916.

57 Eisendrath, Daniel N.: War Injuries of the Blood Vessels. Internat. Abstr. Surg., in Surg., Gynec. & Obst., **26**, 203, 1918.

58 Elkin, D. C.: Vascular Injuries of Warfare. ANNALS OF SURGERY, **120**, 284-306 1944.

59 Elkin, D. C.: Discussion of Paper on Aneurysm by Shumacker.[190] Presented at Sixth Service Command Surgical Conference, 27-28 July 1945, Chicago.

60 Elkin, Daniel C.: Traumatic Aneurysm: The Matas Operation—Fifty-seven Years After. Surg., Gynec. & Obst., **82**, 1-12, 1946.

61 Erasmus, J. F. P.: The Problem of Wound Excision in the Treatment of Vascular Injuries. Proc. Cong. C. M. F. Army Surgeons. February 12-19, 1945. Rome.

62 Foisie, Philip S.: Volkmann's Ischemic Contracture. New England J. Med., **226**, 671-679, 1942.

63 Franz, Carl: Lehrbuch der Kriegschirurgie, Springer-Verlag, Berlin, 1942. (Dritte Auflage).

[64] Freeman, N. E.: Influence of Temperature on the Development of Gangrene in Peripheral Vascular Disease. Arch. Surg., **40**, 326-333, 1940.

[65] Freeman, N. E.: Secondary Hemorrhage Arising from Gunshot Wounds of the Peripheral Blood Vessels. ANNALS OF SURGERY, **122**, 631–640, 1945.

[66] Gage, Mims: Traumatic Injuries to the Peripheral Vessels in both Civil and Military Practice. Surgery, **11**, 983-986, 1942.

[67] Gage, Mims: Traumatic Arterial Aneurysms of the Peripheral Arteries. Pathology, Clinical Manifestations, Diagnosis and Treatment. Am. J. Surg., **59**, 210-231, 1943.

[68] Gage, Mims, and Ochsner, Alton: The Prevention of Ischemic Gangrene Following Surgical Operations upon the Major Peripheral Arteries by Chemical Section of the Cervicodorsal and Lumbar Sympathetics. ANNALS OF SURGERY, **112**, 938-957, 1940.

[69] Gnilorybov, T. E.: One Hundred and Thirty Operations on the Blood Vessels. Khirurgiya No. 8, 40-35 (*sic*), 1942. Moscow. Abstr. Bull. War Med., **4**, 452-453, 1944.

[70] Goodman, Charles: A Histological Study of the Circular Suture of the Blood Vessels. ANNALS OF SURGERY, **65**, 693-703, 1917.

[71] Goodman, Charles: Suture of Blood Vessel Injuries from Projectiles of War. Surg., Gynec. & Obst., **27**, 528-529, 1918.

[72] Goodman, Charles: Surgery of the Heart; Blood Vessels, Thrombosis and Embolism and Blood Transfusion. Cinquième Congrès de la Société Internationale de Chirurgie, Paris, 19-23 July 1920, pp. 244-263.

[73] Goodman, Charles: Suture Repair of War Injuries to the Blood Vessels. J. Internat. Coll. Surgeons, **6**, 127-132, 1943.

[74] Gregoire, R., and Mondor, H.: Notes sur les plaies des vaisseaux. Lyon chir., **14**, 625-639, 1917.

[75] Griffiths, D.: Volkmann's Ischaemic Contracture. Brit. J. Surg., **28**, 239-260, 1940.

[76] Guthrie, C. C.: End-results of Arterial Restitution with Devitalized Tissue. J. A. M. A., **73**, 186-187, 1919.

[77] Von Haberer, H.: Diagnose und Behandlung der Gefässverletzungen. München. med. Wchnschr., **65**, 363-405, 1918.

[78] Von Haberer, Hans: Surgery of the Blood Vessels in Wartime. München. med. Wchnschr., **87**, 849, 1940. Abstr. Internat. S. Digest., **31**, 21-24, 1941.

[79] Haimovici, H.: In a Review of the 46th French Congress of Surgery, October 4, 1937. Translated by Michael DeBakey. Surgery, **3**, 306, 1938.

[80] Harbison, Samuel P.: Preliminary Report on Traumatic Aneurysms. M. Bull, North African Theater Operations, **1**, 29-33, May, 1944.

[81] Harbison, Samuel P.: Experiences with Aneurysms in an Overseas General Hospital. Surg., Gynec. & Obst., **81**, 128-137, 1945.

[82] Hardaium, Jean-Elie-Marie: Hémorrhagies secondaires dans les traumatismes de guerre. Thèse de Paris, 1915. A. Maloine & Fils, Paris, 1915.

[83] Heidrich, Leopold: Über Ursache und Häufigkeit der Nekrose bei Ligaturen grosser Gefässstämme. Beitr. z. klin. Chir., **124**, 607–628, 1921.

[84] Henry, J. P.: Traumatic Vasospasm and Its Relationship to Wounds of the Lower Extremities. Am. J. Surg., **56**, 49-53, 1942.

[85] The Genuine Works of Hippocrates. Translated by Francis Adams. The Williams & Wilkins Co., New York, Baltimore, 1939, **2**, 305.

[86] Holman, Emile: War Injuries to Arteries and Their Treatment. Surg., Gynec. & Obst., **75**, 183-192, 1942.

[87] Holman, E.: Further Observations on Surgery of the Large Arteries. Surg., Gynec. & Obst., **78**, 275-287, 1944.

[88] Holman, Emile, and Edwards, Muriel E.: A New Principle in the Surgery of the Large Vessels: Ligation of the Artery: An Experimental Study. J. A. M. A., **88**, 909-911, 1927.

89 Holmes, W.; Highet, B., and Seddon, H. J.: Ischaemic Nerve Lesions Occurring in Volkmann's Contracture. Brit. J. Surg., 32, 259-275, 1944.

90 Homans, John: Vasomotor and Other Reactions to Injuries and Venous Thrombosis. Am. J. M. Sc., 205, 313-328, 1943.

91 Höpfner, E.: Über Gefaessnaht, Gefaesstransplantation und Reimplantation von amputierten Extremitaeten. Arch. f. klin. Chir., 70, 417-454, 1903.

92 Hotz, G.: Zur Chirurgie der Blutgefaesse. Beitr. z. klin. Chir., 97, 177, 1915.

93 Jacob: Blessures des Vaisseaux. Comptes-Rendus de la Conférence Chirurgicale Interalliée pour l'étude des plaies de guerre. 5° Séance, 16 May 1917. Arch. de Méd. et de Pharm. mil., 68, 328-340, 1917.

94 Jacobson, W. H. A.: The Operations of Surgery, 6th edition by R. P. Rowlands & Philip Turner. J. & A. Churchill, London, 1915. 1, 843, 894.

95 Jeger, Ernst: Die Chirurgie der Blutgefaesse und des Herzens. Hirschwald & Co., Berlin, 1913.

96 Jeger, Ernst: Kriegschirurgische Erfahrungen über Blutgefaessnaht. Beitr. klin. Wchnschr., 51, 1907, 1914.

97 Khenkin, V. L.: Experience of the Treatment of Wounds of Blood Vessels in the Forward Area and at "Army" Level. Khirurgiya, Moscow, 14, 50-57, 1944. Abstr., Bull. War Med., 6, 75, 1945.

98 Killian, H.: Über die Indikation zur Frühoperation von Gefässverletzungen und Aneurysmen. Arch. f. klin. Chir., 204-355, March 26, 1943.

99 Kirtley, James A.: Experiences with Sympathectomy in Peripheral Lesions. ANNALS OF SURGERY, 122, 29-38, 1945.

100 Kirtley, James A.: Arterial Injuries in a Theater of Operations. ANNALS OF SURGERY, 122, 223-234, 1945.

101 Kramarov: Quoted by Aird.[1]

102 Kretzschmann, W.: Ergebnisse der Behandlung groesserer Gefaessverletzungen: 1. Primaere Unterbindung. 2. Primaere Gefaessnaht. 3. Priamaere Amputation. 4. Secundaere Amputation. 5. Konservative Behandlung. 1936, Leipzig, Dissertation.

103 Kroh, Fritz: Frische Schussverletzungen des Gefässapparates: Eine klinische-experimentelle Studie. Beitr. z. klin. Chir., 108, 61-75, 1917.

104 Küttner, H.: Neue Erfahrungen in der Kriegschirurgie der grossen Blutgefässstämme. Klin. Wchnschr., 53, 132–138, 1916.

105 Küttner, Herman, and Baruch, Max: Beiträge zur Chirurgie der grossen Blutgefässstämme: IV. Der traumatisch segmentare Gefässkrampf. Beitr. z. klin. Chir., 120, 1-24, 1920.

106 LaGarde, Louis A.: Gunshot Injuries: How They Are Inflicted, Their Complications and Treatment. William Wood & Co., 1916, New York.

107 Large, Alfred, and Heinbecker, Peter: Refrigeration in Clinical Surgery. ANNALS OF SURGERY, 120, 707-715, 1944.

108 Large, Alfred, and Heinbecker, Peter: The Effect of Cooling on Wound Healing. ANNALS OF SURGERY, 120, 727-741, 1944.

109 Large, Alfred, and Heinbecker, Peter: Nerve Degeneration Following Prolonged Cooling of an Extremity. ANNALS OF SURGERY, 120, 742-749, 1944.

110 Learmonth, J. R.: Repair of Injuries to Blood Vessels. Lancet, 1, 472, 1940.

111 Leriche, R.: De la sympathectomie péri-artérielle et de ses résultats. Presse méd., Paris, 1917, p. 513.

112 Leriche, R.: La Chirurgie de la Douleur. Masson et Cie, Paris, 1940.

112 Leriche, R.: Physiologie Pathologique et Chirurgie des artères. Principes et méthodes de la Chirurgie Artérielle. Masson et Cie, Paris, 1943.

114 Leriche, R., and Heitz, J.: Résultats de la sympathectomie péri-artérielle dans la traitement des troubles nerveux post-traumatiques d'ordre réflexe (type Babinski-Froment). Lyon Chirurg., 14, 754-792, 1917.

115 Leriche, R., and Policard, A.: Ligation of Brachial Artery. Lyon Chirur., 17, 250, 1920. Abstract J. A. M. A., 75, 639, 1920.

116 Leriche, R., and Werquin, M. G.: Effects of Arterial Ligature on the Vasomotor System. Lancet, 2, 296-297, 1940.

117 Lexer, Erich: Die ideale Operation des arteriellen und des arteriellvenösen aneurysma. Arch. f. klin. Chir., 83, 459-477, 1907.

117a Linton, R. R., Morrison, P. J., Ulfelder, H., and Libby, A. L.: Therapeutic Venous Occlusion: Its Effect on the Arterial Inflow to an Extremity as Measured by Means of the Rein Thermostromuhr. Am. Heart J., 21, 721-742, 1941.

118 Loewe, L., Rosenblatt, P., and Lederer, M.: A New Method of Administering Heparin. Proc. Soc. Exper. Biol. & Med., 50, 53, 1942.

119 Longmore, T.: Gunshot Injuries: Their History, Characteristic Features, Complications and General Treatment. Longmans, Green & Co., London, 1877.

120 Love, Albert G.: The Medical Department of the U. S. Army in the World War II, pt. 1, ch. 3, Government Printing Office, Washington, 1927.

121 MacFarlane, J. A.: Wounds in Modern War. J. Bone & Joint Surg., 24, 739-752, 1942.

122 Macpherson, W. G.: Report 14. Port Arthur: The Russian Red Cross Society's Hospital: Statistical Analysis of 2,080 Wounds Treated during the Siege. The Russo-Japanese War. His Majesty's Stationery Office. London, 1908., pp. 281-291.

123 McElvenney, R. T.: The Present Status of Cooling Limbs in Preparation for Surgical Procedures. Am. J. Surg., 58, 110, 1942.

124 Makins, G. H.: The Bradshaw Lecture on Gunshot Injuries of the Arteries. Lancet, 2, 1743-1752, 1913. Also Brit. M. J., 2, 1569-1577, 1913.

125 Makins, George H.: On the Vascular Lesions Produced by Gunshot Injuries and Their Results. Brit. J. Surg., 3, 353-421, 1916.

126 Makins, G. H.: The Hunterian Oration on the Influence Exerted by the Military Experience of John Hunter on Himself and the Military Surgeon of Today. Lancet, 1, 249-254, 1917.

127 Makins, G. H.: Blessures des Vaisseaux. Comptes Rendus de la Conférence Chirurgicale Interalliée pour l'étude des plaies de guerre. 6° Séance, 17 May, 1917. Arch de Méd. et de Pharm. Mil., 68, 341-348, 1917.

128 Makins, G. H.: On Gunshot Injuries to the Blood Vessels. John Wright & Sons, Ltd., Bristol, 1919.

129 Makins, G. H.: Injuries to the Blood Vessels. In Official History of the Great War Medical Services. Surgery of the War, 2, 170-296. His Majesty's Stationery Office, London, 1922.

130 Mason, James M., III, and Giddings, W. Phillip: Experience with Lumbar Sympathetic Ganglionectomy for Wounds of Major Blood Vessels of the Lower Extremity. Surg., Gynec. & Obst., 81, 169-176, 1945.

131 Matas, Rudolph: Surgery of the Vascular System, in Keen, W. W.: Surgery: Its Principles and Practice, by Various Authors. W. B. Saunders Company, Philadelphia and London, 1921. 5, 17-350.

132 Matas, Rudolph: Endo-aneurismorrhaphy. I. Statistics of Operation of Endo-aneurismorrhaphy. II. Personal Experiences and Observations on the Treatment of Arteriovenous Aneurisms by the Intravascular Method of Suture: With Special Reference to the Transvenous Route. Surg., Gynec. & Obst., 30, 456-459, 1920.

133 Matas, Rudolph: Military Surgery of the Vascular System, in Keen, W. W.: Surgery: Its Principles and Practice, by Various Authors. W. B. Saunders Company, Philadelphia and London, 1921. 7, 713-819.

134 Matheson, N. M., and Murray, Gordon: Recent Advances and Experimental Work in Conservative Vascular Surgery. In Surgery of Modern Warfare, Edited by Hamilton Bailey, The Williams and Wilkins Co., Baltimore, 1941. 1, 324-327.

135 Maurer, André: Wounds of the Vessels of the Face, Neck and Limbs: Their Sur

gical Treatment, Based upon Four Hundred and Forty-three Cases. Internat. Clin., **31**, 164-195, 1921.

[136] Maurer, A.: Note sur les plaies vasculaires récentes et leur traitement d'après 444 observations. Mém. Acad. de chir., **65**, 1156-1164, 1939.

[137] Maury, E., and Daban, E.: Un cas d'inhibition segmentaire traumatique de l'artère humérale. Bull. et mém. d. Soc. de chirurgiens de Paris, **45**, 604-611, 1919.

[138] Maybury, B. C.: Treatment of Traumatic False Aneurysm and Arteriovenous Fistula. Bull. War Med., **5**, 417-422, 1945.

[139] Mayfield, Frank H., and Devine, John W.: Causalgia, Surg., Gynec. & Obst., **80**, 631-635, 1945.

[140] Mayfield, Frank H., and Ulmer, Jack L.: Causalgia. Presented at the Sixth Service Command Surgical Conference 27-28 July, 1945, Chicago.

[141] Mignon, A.: Le Service de Santé pendant la Guerre, Tome **2**. 1914-1918, Masson & Cie., Paris, 1926.

[142] Military Surgical Manuals: Vascular Injuries. **5**, 211, Burns, Shock, Wound Healing and Vascular Injuries. Prepared under the Auspices of the Committee on Surgery of the Division of Medical Sciences of the National Research Council. W. B. Saunders Co., Philadelphia and London, 1943.

[143] Ministère de la Guerre. Direction du Service de Santé. Étude de Statistique Chirurgicale Guerre de 1914-1918, Paris, Imprimérie Nationale, Paris, 1924.

[144] Mitchiner, Philip H.: Injuries of Blood Vessels and Their Treatment. St. Thomas' Hosp. Gaz., **38**, 92-96, 1940.

[145] Mitchiner, P. H.: The Treatment of Wounds of Blood Vessels. Post-Graduate Med. J., **16**, 157-161, 1940.

[146] Mocquot, P., and Fey, B.: Gravité des lésions artérielles du membre inférieur dans les plaies de guerre. Rev. de chir., **52**, 241, 1917.

[147] Montgomery, Albert H., and Ireland, Jay: Traumatic Segmentary Arterial Spasm. J. A. M. A., **105**, 1741-1746, 1935.

[148] Montgomery, M. L.: Effect of Therapeutic Ligation on Blood Flow in Cases of Arterial Occlusion. Proc. Soc. Exp. Biol. & Med., **27**, 178-179, 1929.

[149] Moore, B.: Traumatic Lesions of Large Blood Vessels Treated in a Prison Camp in Germany. Australian & New Zealand J. Surg., **13**, 241-243, 1944.

[150] Moure, Paul: Technique des greffes vasculaires appliquées au rétablissement de la continuité des artères. J. de Chir., **9**, 541-560, 1912.

[151] Moure, Paul: Greffe vasculaire; preuve de la vitalité du greffon par une double greffe. Bull. et mém. Soc. Anat. de Paris, **88**, 489-492, 1913.

[152] Murray, Gordon D. W.: Heparin in Thrombosis and Embolism. Brit. J. Surg., **27**, 567-598, 1940.

[153] Murray, Gordon, and Janes, J. M.: Prevention of Acute Failure of Circulation Following Injuries to Large Arteries: Experiments with Glass Cannulae Kept Patent by Administration of Heparin. Lancet, **1**, 6-7, 1940.

[154] Neuhof, Harold, and St. John, Fordyce B.: Infective ("Secondary") Haemorrhages from War Wounds: A Clinical and Pathological Study. Surg., Gynec. & Obst., **29**, 130-141, 1919.

[155] Ochsner, Alton: Indications and Technic for the Interruption of Impulses Traversing the Lumbar Sympathetic Ganglia. Surg. Clin. North America, 1318-1334. October, 1943.

[156] Odom, Charles B.: Causes of Amputations in Battle Casualties: With Emphasis on Vascular Injuries. In Press.

[157] Ogilvie, W. H.: War Surgery in Africa. Brit. J. Surg., **31**, 313-324, 1944.

[158] Von Oppel, W. A.: Zur operativen Behandlung der Arteriovenösen Aneurysmen, Arch. f. klin. Chir., **86**, 31-52, 1908.

[159] Von Oppel, W. A.: Reducierter Blutkreislauf, Part 1, Section VII, Surgery, Discussion No. 3, p. 189. XVIIth International Congress of Medicine, London, 1913. Henry Froude, Oxford University Press, London, 1913.

[160] Von Oppel, W. A.: Wieting's Operation und der reduzierte Blutkreislauf (Wralschebnaja Gaz. 1913 No. 9) Zentralbl. f. Chir., **40**, 1241, 1913.

[161] Von Oppel, W. A.: Die Theorie des umgekehrten und der perversen Blutlaufs in den Extremitäten (Russiki Wratsch 1913, No. 15) Zentralbl. f. Chir., **40**, 1242, 1913.

[162] Otis, George A., and Huntington, D. L.: The Medical and Surgical History of the War of the Rebellion, Part III, Volume II, Surgical History. Government Printing Office, Washington, 1883.

[163] Ottaway, John P., and Foote, John J.: Refrigeration of Wounded Extremities. U. S. Nav. M. Bull., **43**, 1041-1043, 1944.

[164] Parkes, Athol R.: Traumatic Ischemia of Peripheral Nerves with Some Observations on Volkmann's Ischemic Contraction. Brit. J. Surg., **32**, 403-414, 1945.

[165] Payr, Erwin: Beiträge zür Technik der Blutgefass-und Nervennaht nebst Mittheilungen über die Verwendung eines resorbirbaren Metalles in der Chirurgie. Arch. f. klin. Chir., **62**, 67-93, 1900.

[166] Pearse, Herman E., Jr.: A New Explanation of the Improved Results Following Ligation of Both Artery and Vein. ANNALS OF SURGERY, **86**, 850-854, 1927.

[167] Picqué, Robert: Du traitement immédiat des plaies vasculaires dans une ambulance de l'Avant. Bull. et mém. Soc. d. Chirurgiens de Paris, **42**, 682-696, 1916.

[168] Plank, Joseph R.: A Case Report of Bilateral Arteriovenous Aneurysms of the Posterior Tibial Arteries. Surgery, **18**, 391–394, 1945.

[169] Pollock, G. A.: Early Operation for Volkmann's Ischaemic Contracture. Brit. M. J., **1**, 783, 1944.

[170] Pratt, Gerald H.: The Treatment of Traumatic and War Wounds of the Vascular System. Am. J. Surg., **57**, 26-28, 1942.

[171] Pratt, Gerald H.: Surgical Management of Traumatic Lesions of the Arteries. Surg. Clin. North America, **23**, 358-376, April, 1943.

[172] Pridie, K. H.: Gangrene after Arterial Contusion. Lancet, **1**, 267-268, 1943.

[173] Propping, Karl: Über die Ursache der Gangrän nach Unterbindung grosser Arterien. München. med. Wchnschr., **64**, 598-599, 1917.

[174] Punin: Cited by Franz.[63]

[175] Ranzi, Egon: Aneurysma-operationen. Arch. f. klin. Chir., **110**, 530-664, 1918.

[176] Rehn, E.: Das Aneurysma der Arteria subclavia durch Schussverletzung und seine ideal Operation mit freier Venenüberpflanzung. Zent. f. Chir., **69**, 1262, 1275, August, 1942.

[177] Rehn, E.: Grundsätzliche Bemerkungen zur rekonstruktiven Chirurgie des Schussaneurysma. Zentralbl. f. Chir., **70**, 957-965, 1943.

[178] Reneaux, L.: Reconstruction of Popliteal Artery. Brasil-med., **34**, 509, 1920. Abstract J. A. M. A., **75**, 756, 1920.

[179] Richards, Victor: Refrigeration Anesthesia in Surgery. ANNALS OF SURGERY, **119**, 178-200, 1944.

[180] Rogers, L.: Physiological Considerations in Vascular Surgery: Ligature of Main Arteries to the Limbs. M. J. Australia, **1**, 505, 1945.

[181] Rose, Charles A.; Hess, Orvan W., and Welch, Charles Stewart: Vascular Injuries of the Extremities in Battle Casualties. In Press.

[182] Salomon, R.: Beiträg zur Lehre der Arteriovenösen Schussaneurysmen. Beitr. z. klin. Chir., **113**, 369-410, 1918.

[183] Sandzen, Sigurd C., and Evans, Byron H.: Peripheral Arterial Lesions of Warfare. In Press.

[184] Schloessman: Über Spätblutungen nach Schussverletzungen. Beitr. z. klin. Chir., **96**, 129-143, 1915.

[185] Schneider, H., and Batzner, K.: Die Behandlung der Aneurysmen der Arteria poplitea und ihrer Äste. Zentralbl. f. Chir., **70**, 965–975, July 3, 1943.

[186] Sehrt, E.: Über die Kunstliche Blutleehre von Gliedmassen und unterer Körpeshälfte sowie über die Ursache der Gangrän des Gliedes nach Unterbindung der Arterie allein. Med. Klin., **12**, 1338-1341, 1916.

187 Sencert, L.: Le Traitement des plaies Vasculaires à l'Avant. Lyon Chir., **14,** 640-684, 1917.

188 Sencert, L.: Wounds of the Vessels. University of London Press, Ltd., London, 1918.

189 Sencert, L.: La Chirurgie des gros Vaisseaux: 1. Les Blessures des Vaisseaux. Cinquième Congrès de la Société Internationale de Chirurgie, Paris, 19–23 Juillet, 1920. M. Hayez, Brussels, 1921, pp. 77-137.

190 Schumacker, Harris B.: Experience in the Treatment of 195 Aneurysms. Presented at the Sixth Service Command Surgical Conference, 27-28 July, 1945, Chicago.

191 Schumacker, Harris B.; Olsson, Paul B., and Carter, Kenneth L.: Sympathectomy in Vascular Disorders. Presented at the Sixth Service Command Surgical Conference, 27-28 July, 1945, Chicago.

192 Simeone, F.: Wounds of the Arteries of the Extremity. Report to The Surgeon General from The Mediterranean Theater of Operations.

193 Snyder, John M.: Vascular Wounds: Report of a Series of 107 Cases Encountered in a Forward Evacuation Hospital. In Press.

194 Soubbotitich, V.: Military Experiences of Traumatic Aneurysms. XVIIth International Congress of Medicine. Section VII, Surgery, Part II, pp. 179-185, 1913. Oxford University Press, London, 1914.

195 Soubbotitich, V.: Quelques Considérations sur les Aneurismes Traumatiques. Bull. et mém. Soc. de Chir. de Paris, **42,** 698-708, 1916.

196 Soubeyran: A propos de la Stupeur Artérielle. Bull. et mém. Soc. de Chir. de Paris, **45,** 908-910, 1919.

197 Taylor, F. W., and Tondreau, R. L.: Traumatic Arterial Spasm Resulting in Gangrene of the Upper Extremity. U. S. Nav. M. Bull., **42,** 911-915, 1944.

198 Theis, F. W.: Ligature of Artery and Concomitant Vein in Operation on Large Blood Vessels. Arch. Surg., **17,** 244, 1928.

199 Tuffier: De l'intubation dans les plaies des grosses artères. Bull. Acad. de méd., Paris, **74,** 455-460, 1915.

200 Tuffier: Contemporary French Surgery. Brit. J. Surg., **3,** 100-112, 1915.

201 Tuffier: A propos des plaies des artères. Bull. et Mém. Soc. de Chir. de Paris, **43,** 1469-1471, 1917.

202 Tuffier: French Surgery in 1915. Brit. J. Surg., **4,** 420-432, 1917.

203 Turovets, I. G.: Gunshot Wounds of the Blood Vessels. Khirurgia No. 5-6, pp. 35-46, 1942. Abstract Am. Rev. Soviet Med., **1,** 41, 1943; and Bull. War Med., **4,** 628-629, 1944.

204 Van Kend: Sur les blessures des vaisseaux. Arch. de Méd. et Pharm. mil., **68,** 348-349, 1917.

205 Veau: Le Stupeur Artérielle. Presse méd., **26,** 425–426, August 15, 1918.

206 Viannay, Charles: La Stupeur Artérielle traumatique. Presse méd., **27,** 106–107, 1919.

206a Warren, Richard: Observations of War Wounds of Arteries. In Press.

207 Warthmüller, Hans: Über die Bisherigen Erfolge der Gefässtransplantation am Menschen. G. Neuenbann, Jena, 1917, p. 39.

208 Waugh, W. Grant: Secondary Hemorrhage, in Surgery of Modern Warfare, Edited by Hamilton Bailey, The Williams and Wilkins Co., Baltimore, 1941, **1,** 328-332.

209 White, James C., and Smithwick, Reginald H.: The Autonomic Nervous System. Anatomy, Physiology, and Surgical Application, The Macmillan Co., New York, 1941.

210 Wilson, W. C.: Occlusion of the Main Artery and Main Vein of a Limb. Brit. J. Surg., **20,** 393-411, 1933.

211 Zahrodnicky: Die Behandlung der Unechten Aneurysmen. Wien. klin. Wchnschr., **28,** 999-1007, 1915.

COL. MICHAEL E. DEBAKEY, M.C.
Office of the Surgeon General
Washington 25, D. C.

TRAUMATIC ARTERIOVENOUS FISTULA INVOLVING THE ABDOMINAL AORTA AND THE INFERIOR VENA CAVA*

JOHN DEJ. PEMBERTON, M.D., PHILIP H. SEEFELD, M.D.,

DIVISION OF SURGERY

AND

NELSON W. BARKER, M.D.,

DIVISION OF MEDICINE

MAYO CLINIC,

ROCHESTER, MINNESOTA

RECENTLY we have encountered and apparently have successfully repaired surgically an intra-abdominal traumatic arteriovenous fistula occurring between the abdominal aorta and the inferior vena cava, and situated at the level of the second portion of the duodenum. The fistula resulted from a gunshot wound.

We believe that a report of this case and the operation should be of interest not only because of the rarity of arteriovenous fistulae occurring at this site, but also because there have been satisfactory evidence and sufficient lapse of time since surgical repair to indicate that the patient has been relieved of a life-threatening cardiovascular disturbance. So far as we have been able to determine, this appears to be the only reported case in which an arteriovenous fistula between the abdominal aorta and the inferior vena cava in this site has been successfully repaired by surgical means.

Lehman, in 1938, reported a case in which an attempt was made to repair a spontaneous arteriovenous fistula that occurred between the abdominal aorta and the inferior vena cava, but death occurred from hemorrhage 15 hours after operation. Bigger, in 1944, reported a case in which a traumatic arteriovenous fistula involved the distal portion of the abdominal aorta and the inferior vena cava. The fistula was the result of a bullet wound. Surgical repair was carried out by proximal ligation of the aorta with tape and closure of the fistula by means of silk sutures passed through the wall of the unopened inferior venâ cava. Three months after operation, the tape cut its way through the wall of the aorta and caused fatal hemorrhage.

Linton and White recently reported the successful repair of a traumatic arteriovenous fistula which occurred between the right common iliac artery and the inferior vena cava eight months after an operation had been performed for the removal of a protruded intervertebral disk. After preliminary sympathectomy, the portion of the right common iliac artery containing the fistula was ligated and divided proximally and distally to the fistula. Ligation of the right external iliac vein also was carried out.

Case Report.—A man, age 28, was first seen at the Mayo Clinic in July, 1943. In May, 1937, a stray 30-caliber rifle bullet had entered the right lower lateral portion of his thorax, between the fifth and sixth ribs. Complete sensory and motor paralysis of the lower extremities had developed immediately, and had persisted for one month. There

had been no loss of sphincteric control. There had been a gradual return of sensation in the lower extremities. This had been followed by a slow return of motor function; about two months after the injury the patient had been able to be up and about, with only a slight limp involving the left leg. The limp also had disappeared gradually. For more than a year and a half he had been up and about. He had been able to take part in sports and had returned to work.

In March, 1939, the patient had begun to experience episodes of weakness, nausea and varying degrees of edema of the ankles. He also had noted that he tired easily. These symptoms had continued until December, 1940, when dyspnea had developed and the edema of the ankles had become more severe. He had been forced to stop working and had been placed on a cardiac regimen by his physician. This had consisted of rest in bed and the administration of digitalis for three months. His general condition had improved and in
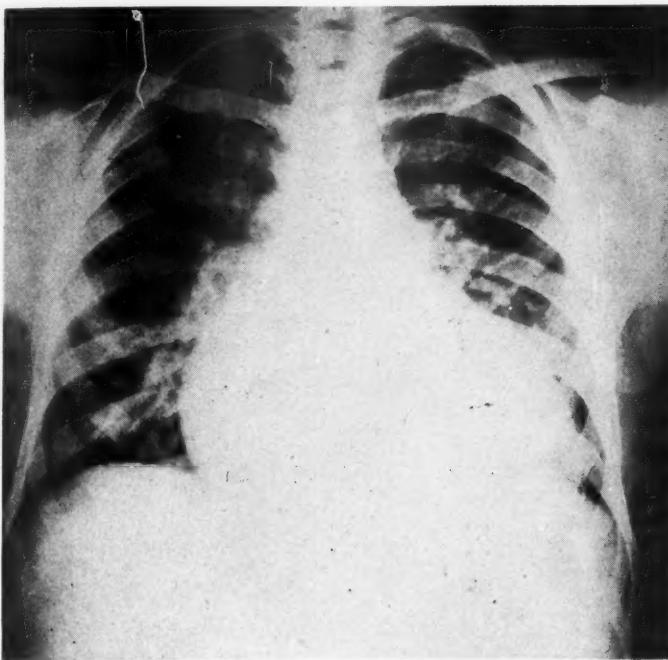
FIG. 1.—Roentgenogram of the thorax made July, 1943, showing marked cardiac enlargement and bilateral pulmonary passive congestion.

spite of several episodes of pneumonia of mild degree, he had recovered sufficiently to resume his occupation in July, 1942. He had continued to work for 11 months, but in June, 1943, fatigue and edema of the legs recurred and he came to the clinic one month later.

The patient was a little less than medium height and weighed about 130 pounds (59 Kg.). His blood pressure was 180 mm. of mercury systolic and 80 mm. diastolic, and his pulse rate was 80. General physical examination revealed marked cardiac enlargement and a soft apical systolic murmur. Auscultation revealed a loud machine-like bruit which could be heard over the entire abdomen as well as over the entire back from shoulders to buttocks. The bruit was continuous and was accentuated with each systole. The maximal intensity of the bruit was in the right upper quadrant of the abdomen, just below the costal margin, but it was transmitted downward to the area overlying the external iliac arteries.

The values for the hemoglobin and the erythrocyte and leukocyte counts were normal. The Kline test on the serum was negative. The value for the blood urea was 36 mg. per 100 cc. Urinalysis revealed moderate albuminuria and a few granular casts and erythrocytes. Roentgenologic examination of the thorax revealed marked cardiac enlargement and bilateral pulmonary congestion (Fig. 1). The electrocardiographic tracing revealed left axis deviation, diphasic T waves in leads I and II and in precordial lead IV R, and delayed A-V conduction (P. R. interval 0.24 second). Roentgenograms disclosed what was described as a soft-tissue mass with a calcified periphery, situated to the left of the upper portion of the lumbar segment of the spinal column. Just below this mass, an opaque foreign body, which resembled a bullet, was seen (Fig. 2). An excretory urogram revealed that the excretory function of the kidneys was normal and that there was no gross deformity of either kidney. Neurologic examination did not disclose any abnormality.
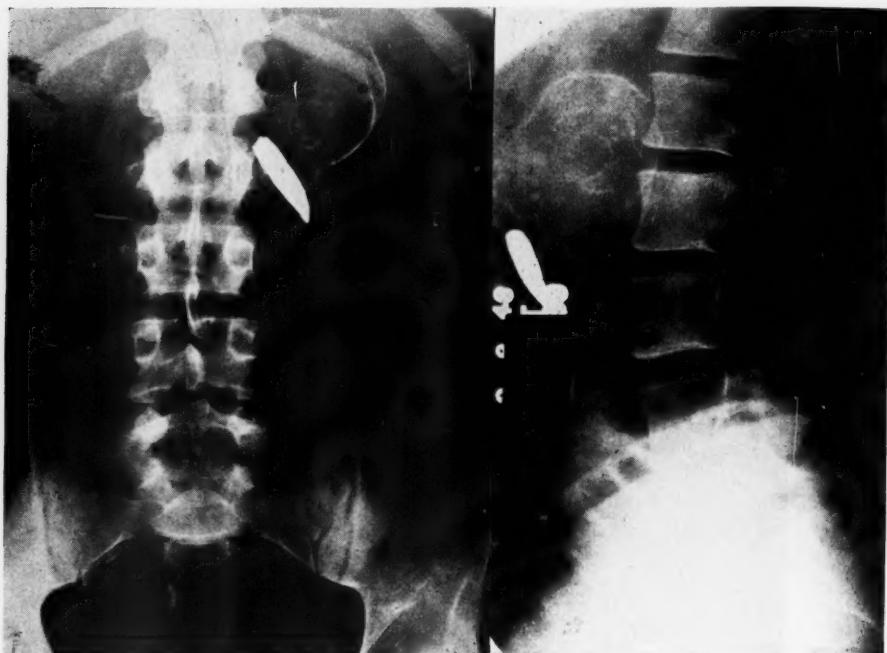
FIG. 2.—Roentgenograms, anteroposterior and lateral, made July, 1943, showing a soft-tissue mass with a calcified periphery situated to the left of the first and second lumbar vertebrae. The rifle bullet is visible just below the mass.

At this time, it was felt that the patient had an aneurysm of the abdominal aorta and also an arteriovenous fistula between the abdominal aorta and inferior vena cava, the exact site of which could be determined only by surgical exploration. It was felt that he had definite congestive heart failure as the result of the arteriovenous fistula and that unless the fistula could be closed the congestive heart failure would be progressive and fatal. The patient was advised to submit to surgical exploration to determine the exact site and the possibility of repair of the fistula but he preferred to postpone the operation.

The patient returned home and was able to do desk work for two or three hours a day. Nine months later, edema of the legs, dyspnea and cough developed in spite of digitalization. These symptoms were controlled with increasing difficulty by intravenous injections of salyrgan. He returned to the clinic in October, 1944, because of severe congestive heart failure.

Upon his arrival, he was markedly dyspneic at rest. His blood pressure was 190 mm.

systolic and 100 mm. diastolic. The heart was greatly enlarged; the apical impulse was in the midaxillary line at the level of the sixth intercostal space. The precordial systolic murmur had increased in intensity. There were many moist râles at the bases of the lungs, and the liver extended 3.25 inches (8.2 cm.) below the right costal margin. There was marked peripheral edema in both lower extremities. The loud machine-like bruit heard previously over the abdomen and back was still present. The value for the blood urea was 46 mg. per 100 cc. A roentgenogram of the thorax showed extreme cardiac enlargement and severe pulmonary congestion (Fig. 3). Roentgenographic examination of the abdomen again revealed an irregular globular-shaped ring of calcification just to the left of, and slightly anterior to, the first and second lumbar vertebrae. An excretory urogram, again, did not disclose any abnormality. The bullet was visible slightly below and anterior to the calcified mass. The patient decided to undergo surgical exploration.
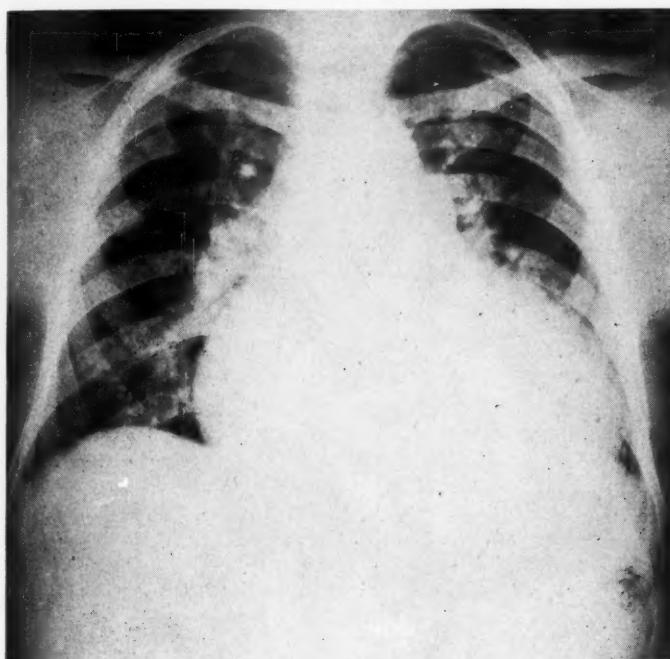
Fig. 3.—Roentgenogram of the thorax made October, 1944, showing extreme cardiac dilatation and passive congestion of the lungs.

He was hospitalized and placed on a cardiac regimen in preparation for operation. He was kept in bed and one cat unit of digitalis was administered daily. Four grams of ammonium chloride was administered daily for ten days. He was given a salt free diet, and his oral intake of fluids was limited to 1,000 cc. daily. Eight intravenous injections of salyrgan (2 cc. each) were given during a period of 18 days. Satisfactory diuresis occurred and he gradually lost 20 pounds (9.1 Kg.). It was felt that this represented edema fluid. His dyspnea disappeared and his liver became smaller. A few râles persisted at both the bases of the lungs. It was decided that his condition was satisfactory for surgical exploration.

Operation.—November 13, 1944: Through a right midrectus incision, under nitrous oxide-oxygen ether anesthesia administered intratracheally, the abdomen was explored. Palpation of the contents of the abdomen revealed a large tumor mass, 6 to 8 cm. in diameter. The mass was situated beneath the pancreas and extended across the bodies of the first and second lumbar vertebrae to the left side. There was a purring thrill which was most intense on the right side.

583

After the second portion of the duodenum had been mobilized, the hugely dilated inferior vena cava was exposed (Fig. 4). The vena cava was 5 to 6 cm. in diameter; it was adherent to the aorta and no distinct line of demarcation was apparent between the two vessels. The aorta appeared to be dilated; the dilatation was greatest above the exposed portion of the two vessels. When the aorta was palpated through the wall of the vena cava, the rush of blood through a fistulous opening could be felt. By pressing against the side of the aorta, through the wall of the vein, the fistulous opening could be blocked, and when this was done there was a distinct elevation of the blood pressure, which fell rapidly when pressure against the fistula was released. The opening between the aorta and vena cava was about 1 to 1.5 cm. in diameter when palpated through the wall of the vena cava.

After careful dissection, a cotton tape was placed around the vena cava above and below the fistulous tract. Then, while the assistant compressed the aorta with his fingers
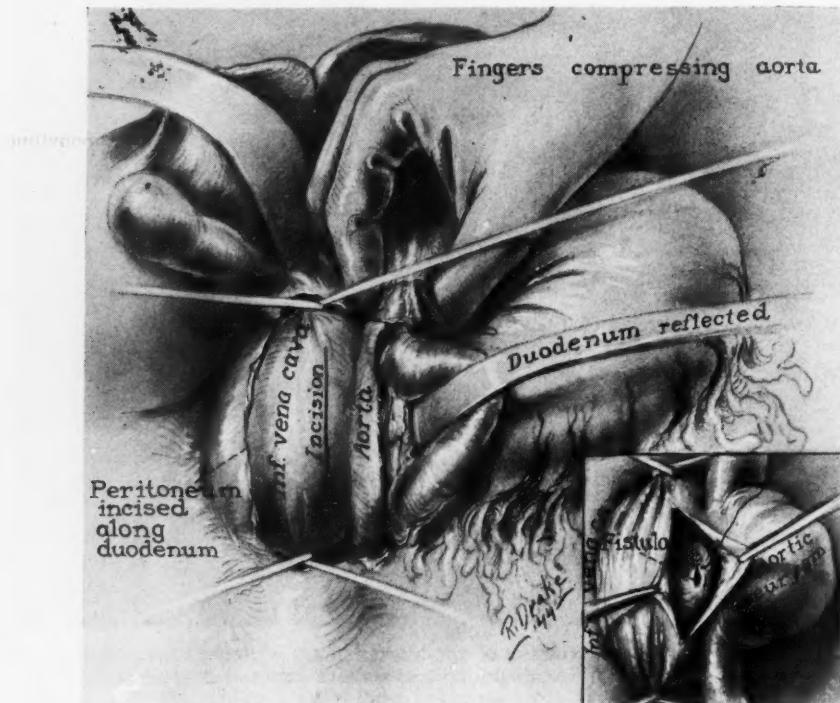
FIG. 4.—Exposure of the dilated inferior vena cava and aorta at the site of the fistula, after mobilizing the duodenum and head of the pancreas. The line of incision into the vena cava is shown. Inset shows the repair of the fistulous opening after opening the vena cava. Also shown is the aortic aneurysm to the left.

just below the diaphragm, bleeding through the fistulous opening could be controlled. A longitudinal incision was then made in the wall of the vena cava opposite the fistula, and by compressing the vein both above and below the fistula a reasonably dry field could be obtained so that the edges of the fistulous opening could be approximated with one row of silk sutures. When the compressed aorta was released, there was no leakage of blood through the closed fistula. The opening in the vena cava was closed with two rows of silk suture. There was some distention of the vena cava after closure, but the condition of the patient remained good. The tape which had been placed around the vena cava above the fistula was removed; however, the tape below the fistula was allowed to remain and

its ends were brought out of the abdomen through the incision with the anticipation that, if postoperative bleeding should occur, traction on this tape would aid in its control. Five grams of sulfathiazole crystals were placed in the abdomen and the wound was closed without drainage. During the operation, a transfusion of 1,500 cc. of whole blood was given. The condition of the patient was excellent when he left the operating room. A record of the blood pressure and pulse made at intervals of 15 minutes during the operation revealed a lowering of both systolic and diastolic pressure, with a notable decrease of the pulse pressure, as well as a slowing of the pulse rate; these changes occurred simultaneously with closure of the fistula (Fig. 5). The blood pressure, which before operation had been 160 mm. systolic and 82 mm. diastolic decreased to 130 mm. systolic and 70 mm. diastolic after operation. The pulse pressure decreased from 78 mm. to 60 mm. and the pulse rate decreased from 110 to 100 beats per minute.

On the following day, the patient's rectal temperature rose to 103° F., where it remained for six days before it suddenly fell to normal. A roentgenogram of the thorax showed evidence of mild passive congestion, but there was no evidence of pneumonia. The pulse rate persisted at 110 to 120 for six days but the pulse was regular and of good quality.

During the first six postoperative days the output of urine was low. The value for the blood urea increased to 162 mg. per 100 cc. by the fourth day. Intravenous administration of a 10 per cent solution of glucose in distilled water, digitalis, and aminophylline caused a great increase in the urinary output and the value for the blood urea dropped steadily to a normal level by the sixth postoperative day.

The patient was allowed out of bed on the 13th postoperative day. At this time, a roentgenogram of the thorax revealed a marked reduction in the size of the heart and did not disclose any evidence of pulmonary congestion (Fig. 6).

The patient's strength steadily improved and he was dismissed from the hospital on the 24th postoperative day. During the convalescent period of 23 days in the hospital, the blood pressure remained relatively high, but the pulse pressure and the pulse rate remained at more nearly normal levels (Fig. 7).

At no time since the operation has there been any audible murmur over the abdomen. There has been no dyspnea on mild exertion, and the heart sounds have remained of good quality. The systolic murmur, which was heard at the precordium prior to operation, disappeared. Arterial

FIG. 5.—Record of blood pressure and pulse rate at 15-minute intervals during operation.

pulsation in the lower extremities has remained good. Sixty-four days after the operation, the patient's referring physician found that the blood pressure was 125 mm. systolic and 90 mm. diastolic.

When the patient returned to the clinic for a check-up five months after the repair of the fistula, no evidence of recurrence could be found. There was no dyspnea on moderate exercise, although the blood pressure had reached a level of 170 mm. systolic and 130 mm. diastolic and the heart was found to have remained moderately enlarged. The patient had been doing clerical work daily for a number of weeks and said that his health was excellent.

585

The patient returned to the clinic for a brief check-up November 19, 1945, approximately one year after the operation. He had been feeling well and had been working, but he had had an attack of acute asthmatic bronchitis and an episode of congestive heart failure one month previously. Under treatment he had recovered rapidly from this and was again ambulatory and working. There was no evidence of recurrence of the fistula. Cardiac hypertrophy and hypertension had persisted.

COMMENT.—Since the first accurate description by William Hunter, in 1761, of peripheral arteriovenous fistula, and its local signs and symptoms, much has been written and many studies have been carried out to clarify the changes in physiology and the cardiovascular disturbances which may be produced by this lesion. The majority of the reported studies and observations
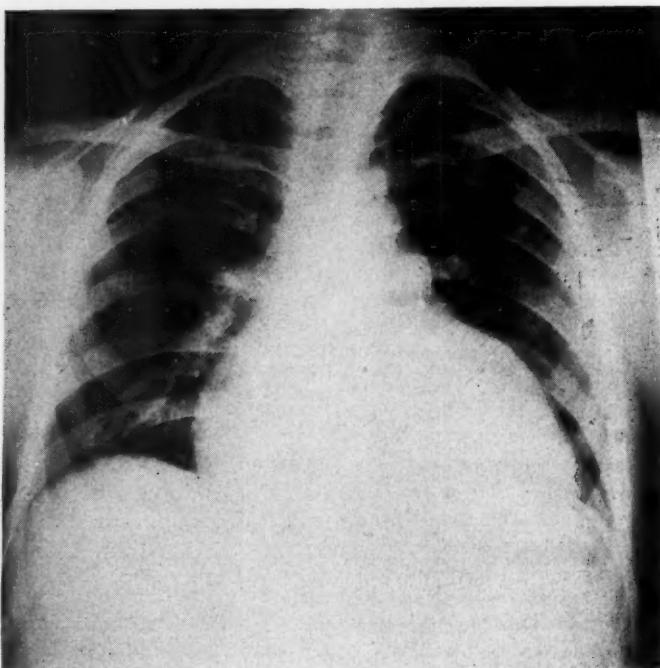
FIG. 6.—Roentgenogram of the thorax made 13 days after operation, showing a marked reduction in the size of the heart and the absence of pulmonary congestion.

have been primarily concerned with arteriovenous aneurysms and fistulae occurring in the extremities. This is readily understood when it is kept in mind that a large majority of abnormal arteriovenous communications occur at these sites.

In the consideration of abnormalities of the larger vessels, it has been recognized that the physiologic effects of arteriovenous fistulae are more complex than those of arterial aneurysms. The former have a tendency to produce generalized disturbances, while the latter result in more localized changes in the region supplied by the vessel involved. Studies and observations by Reid,[15-17] Holman,[4-7] Matas,[14] Makins,[11, 12] and many others, have served to emphasize

the serious and often life-threatening effects of abnormal arteriovenous communications and have contributed notably to the development of adequate methods of management.

It is a well-known fact that a traumatic arteriovenous fistula between a large artery and vein in an extremity creates a definite alteration of cardiovascular physiology. It lowers the diastolic arterial blood pressure by decreasing peripheral arterial resistance. It produces more or less ischemia of the distal part of the extremity by shunting blood away from the extremity. It increases venous pressure and venous congestion in the extremity to a marked degree, and this increased venous pressure extends back to the right auricle—probably the most serious disturbance of all. The heart attempts to compensate for increased return of venous blood and decreased peripheral arterial resistance
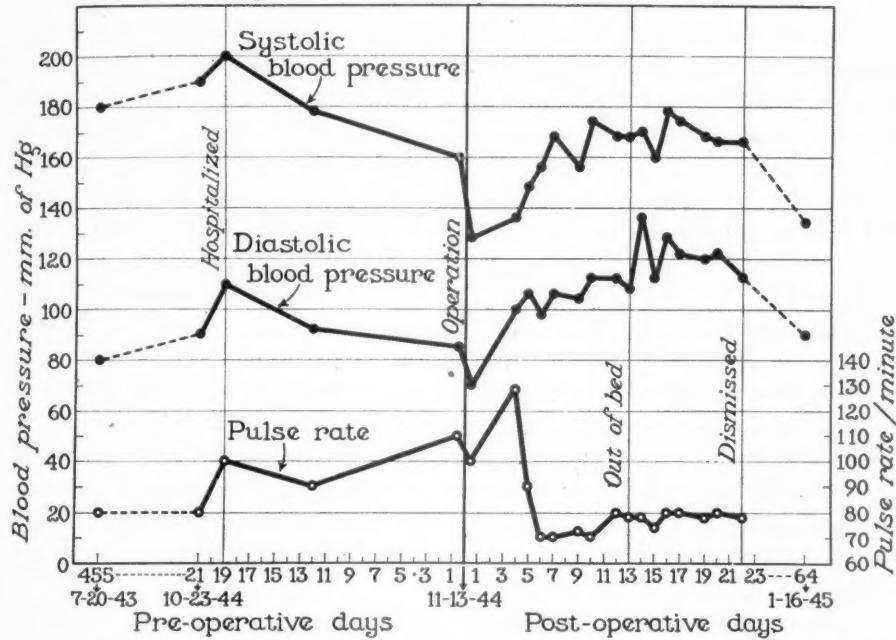
FIG. 7.—Record of blood pressure and pulse rate at intervals from the first admission through the period of convalescence from operation, demonstrating postoperative decrease of pulse pressure and lowering of the pulse rate.

by tachycardia and increased contractions, but its function continues to be impaired. Although the heart may gradually undergo hypertrophy and remain compensated for years, congestive heart failure ultimately will develop and this threat of congestive heart failure is the main reason why it is advisable to close such a fistula surgically before too much damage is done to the overburdened, overworked myocardium.

It would seem obvious that a large fistula between the aorta and inferior vena cava would create a much greater disturbance in cardiac physiology than would a fistula between an artery and vein of an extremity. It probably pro-

587

duces less peripheral ischemia and congestion distal to the fistula because these are distributed over a greater vascular bed.

The case which we have reported illustrates that progressive and serious congestive heart failure develops as the result of such a fistula.

Little has been written concerning arteriovenous fistulae occurring within the abdomen, principally because of the rarity of their occurrence at this site and secondly because of the difficulties which are encountered in their repair by surgical means. It is probable that the rarity of occurrence of traumatic arteriovenous fistulae between great vessels within the abdomen is due, in part, not only to their protected situation deep within the body cavity but also to the lack of surrounding tissue which might serve to support and reinforce an injury to these vessels. Free and exsanguinating hemorrhage, rather than formation of a localized hematoma, undoubtedly is the most frequently occurring consequence of trauma involving the aorta and vena cava. It is also probable that the fact that both aorta and vena cava were injured by the bullet instead of the aorta alone actually saved the patient's life, since this permitted bleeding from the aorta into the vena cava rather than into the anterior lumbar tissues and peritoneal cavity.

In recent literature attention has been drawn to the applicability of occlusion of the abdominal aorta, a procedure necessary for the cure of most aneurysms and fistulae in this region. Bigger and Elkin, among others, reviewed the literature from the first recorded instance of ligation of the abdominal aorta performed by Sir Astley Cooper in 1817, up to 1940, and found that although the abdominal aorta had been ligated in 28 instances, in only seven was survival of life sufficiently long to demonstrate that occlusion of this vessel is not necessarily fatal. Elkin emphasized that, aside from the technical difficulties involved in ligating the aorta, there are other features which may account for the hesitancy to occlude completely this vessel, such as the site of the aneurysm or fistula, the lack of efficient collateral circulation about a lesion at this site, the effect of ligation on the heart, and the problem of obtaining a type of ligature and a technic of occlusion which would preclude cutting or rupture of the vessel or reopening of the channel.

Arteriovenous fistulae involving the aorta and vena cava may be congenital or acquired. The acquired type includes both spontaneous and traumatic fistulae. Most of the arteriovenous fistulae that involve the aorta and vena cava are traumatic; those of the spontaneous type are almost all the result of syphilitic arterial disease. Spontaneous arteriovenous fistulae are unusual below the diaphragm and the majority occur within the thorax. Schweiger, Burchell and Baggenstoss were able to find 124 cases of spontaneous communications between large arteries and veins of the thorax in a review of the literature up until 1938. In a recent report of great interest, Alexander and Byron described the successful surgical removal of an aneurysm of the upper part of the descending portion of the thoracic aorta in which ligation of the aorta was successfully accomplished. However, the patient already had a congenital coarctation of the aorta. Ryle, described a pathologic specimen placed in Guy's Hos-

pital museum, in 1892, illustrating a fistula between the inferior vena cava and the abdominal aorta at its bifurcation. Matas,[13] in 1909, stated that until that time Boinet had found only 20 cases of arteriovenous fistula involving the abdominal aorta and inferior vena cava in a series of 114 cases of the spontaneous type. Lehman, reviewing the subject up until 1938, was unable to find any additional cases reported between 1909 and 1938. In none of these cases had successful surgical repair been accomplished.

SUMMARY

This report is based on a case in which a traumatic arteriovenous fistula was caused by a bullet wound, situated between the inferior vena cava and abdominal aorta, at the level of the first and second lumbar vertebrae. The fistula was repaired surgically, and up to the present time the patient has not exhibited any symptoms or signs of recurrence of the fistula.

This case, and the operation, should be of interest because of the unusual site of the fistula and because it is believed to be the only reported case in which the patient has survived a reasonable length of time after surgical repair to furnish evidence that the operation has been successful.

REFERENCES

[1] Alexander, John, and Byron, F. X.: Aortectomy for Thoracic Aneurysm. J. A. M. A., **126,** 1139–1145, December 30, 1944.

[2] Bigger, I. A.: Treatment of Traumatic Aneurysms and Arteriovenous Fistulas. Arch. Surg., **49,** 170-179, September, 1944.

[3] Elkin, D. C.: Aneurysm of the Abdominal Aorta: Treatment by Ligation. ANNALS OF SURGERY, **112,** 895–908, November, 1940.

[4] Holman, Emile: The Physiology of an Arteriovenous Fistula. Arch. Surg., **7,** 64–82, July, 1923.

[5] Holman, Emile: Arteriovenous Aneurysm: Its Physiologic Effects upon the Circulation and their Importance in Relation to Surgical Treatment. California & West. Med., **30,** 307–313, May, 1929.

[6] Holman, Emile: The Anatomic and Physiologic Effects of an Arteriovenous Fistula. Surgery, **8,** 362–382, August, 1940.

[7] Holman, Emile: Further Observations on Surgery of the Large Arteries. Surg., Gynec. & Obst., **78,** 275–287, March, 1944.

[8] Hunter, William: Further Observations upon a Particular Species of Aneurism: Observations on Aneurism. In The Sydneham Society, Translated by J. E. Erichsen, London, C. and J. Adlard, 1844, pp. 160–170.

[9] Lehman, E. P.: Spontaneous Arteriovenous Fistula between the Abdominal Aorta and the Inferior Vena Cava: Case Report. ANNALS OF SURGERY, **108,** 694–700, October, 1938.

[10] Linton, R. R., and White, P. D.: Arteriovenous Fistula between the Right Common Iliac Artery and the Inferior Vena Cava: Report of a Case of its Occurrence following an Operation for a Ruptured Intervertebral Disk, with Cure by Operation. Arch. Surg., **50,** 6–13, January, 1945.

[11] Makins, G. H.: Gunshot Injuries of the Arteries. London, Henry Frowde, Hodder & Stoughton, 1914, 64 pp.

[12] Makins, G. H.: On Gunshot Injuries to the Blood Vessels: Founded on Experience Gained in France during the Great War, 1914–1918. Bristol, John Wright and Sons, Ltd., 1919, chap. 12, pp. 113-126.

[13] Matas, Rudolph: Surgery of the Vascular System. In: Keen, W. W. and Da Costa, J. C.: Surgery: Its Principles and Practice. Philadelphia, W. B. Saunders Company, 1909, vol. 5, p. 293.

[14] Matas, Rudolph: On the Systemic or Cardiovascular Effects of Arteriovenous Fistulae: A General Discussion Based upon the Author's Surgical Experience. Tr. South. S. A., 36, 623–677, 1923.

[15] Reid, M. R.: The Effect of Arteriovenous Fistula upon the Heart and Blood Vessels; an Experimental and Clinical Study. Bull. Johns Hopkins Hosp., 31, 43–50, February, 1920.

[16] Reid, M. R.: Abnormal Arteriovenous Communications, Acquired and Congenital. III. The Effects of Abnormal Arteriovenous Communications on the Heart, Blood Vessels and other Structures. Arch. Surg., 11, 25–42, July, 1925.

[17] Reid, M. R.: Abnormal Arteriovenous Communications—Acquired and Congenital. IV. The Treatment of Abnormal Arteriovenous Communications. Arch. Surg., 11, 237–253, August, 1925.

[18] Ryle, J. A.: Arteriovenous Fistula: An Historical Note. Guy's Hosp. Rep., 90, 129–133, 1940-1941.

[19] Schweiger, L. R., Burchell, H. B., and Baggenstoss, A. H.: Spontaneous Arteriovenous Communication between the Aorta and Superior Vena Cava. Ann. Int. Med., 19, 1029–1034, December, 1943.

urgery
1946

Costa,
Com-

ulae:
h. S.

ssels;
Feb-

nital.
Blood

nital.
., II,

129-

enous
., 19,

CIRSOID ANEURYSM OF THE SCALP*

REPORT OF FOUR CASES

Colonel Daniel C. Elkin, M.C.

MEDICAL CORPS, ARMY OF THE UNITED STATES

FROM THE VASCULAR SURGERY CENTER, ASHFORD GENERAL HOSPITAL, WHITE SULPHUR SPRINGS, WEST VIRGINIA.

IT IS WELL KNOWN THAT TRAUMA, frequently inconsequential, may be the starting point of vascular tumors which are not only disfiguring but are definitely hazardous to life because of the possibility of severe hemorrhage from them. Therefore, it might be expected that war injuries would give rise to such tumors in increasing numbers.

It is the purpose of the present report to call attention to a particular lesion of this type; namely, that which affects the scalp and which arises either independently or through the existence of a preëxisting vascular abnormality of a congenital angiomatous nature. Four lesions of this character, and in this location, have been encountered in the course of performing operations upon approximately 470 aneurysms and arteriovenous fistulae, which resulted from wounds of warfare.

This condition must have been recognized from the earliest times in view of its striking characteristics and it is not at all improbable that some ancient example may have given rise to the legend of the serpents in the hair of Medusa. The term *aneurysme cirsoide* (varix-like) was first used by Breschet, in 1833. Other designations such as *aneurysma serpentinum* (Cruveilhier), and *aneurysma racemosum* (Virchow) have been introduced into the literature, but the term "cirsoid" has been generally accepted in English literature as a descriptive term for these lesions.

Congenital telangiectases, nevi, or angiomas which occur most commonly on the face and scalp may be the starting point of these tumors, particularly if intermediary trauma or long continuous irritation has occurred, as was true in Case 4. On the other hand, multiple communication between vessels may follow trauma without the apparent presence of a preëxisting vascular lesion, as was seen in the other three cases. When contributing arteries and outgoing veins form multiple anastomoses, the lesion becomes a diffuse arteriovenous fistula, and to these the term "cirsoid" is generally applied.

One of the most remarkable examples of this condition is the case reported by H. Müller,[1] in 1891, from the Clinic of Paul Bruns. This paper was accompanied by a drawing showing the postmortem dissection of the lesion, which is reproduced here (Fig. 1). It is the purpose of the present communication merely to record four outspoken examples of cirsoid aneurysm of the scalp, without attempting to cover the literature on this extensive subject.

The question of an intracranial extension of the lesion or extracranial

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4–6, 1945, Hot Springs, Virginia.

manifestation of a primary intracranial varix should always be borne in mind since there are unquestionably reported instances in which this has occurred. Such was not the case in the four patients here reported, since communicating vessels extending through the skull were not encountered.

A number of these cases have been reported and many have been success-
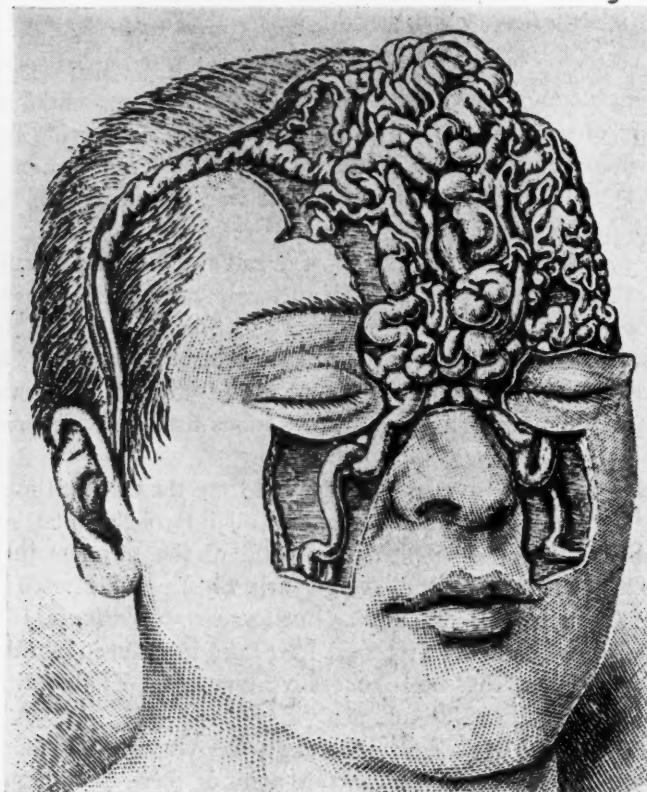

Fig. 1.—Case 1: Dissection of a cirsoid aneurysm of the scalp (after H. Müller).

fully treated by a variety of methods—carotid ligation; multiple ligation of the lesion itself; obliteration with the galvanocautery; by the injection of thrombosing solutions; or by extirpation. The latter method is undoubtedly more certain of cure, and the method of choice.

All of these patients were treated by a similar operative procedure. As a preliminary step in the operation the principal artery or arteries, leading to the lesion were independently ligated. A flap of scalp, horseshoe in shape, was turned down in order to expose the lesion from the underside. In making this incision care was taken to include the galea in the flap. In other words, the incision was carried down to the pericranium and all tissues superficial to that were reflected with the lesion. Hemostasis was obtained by finger pressure and by individually ligating and dividing each vessel as it was encountered in

the incision. The main vessels, including the central portion of the lesion, were completely excised from the underside of the flap, particular care being taken not to button-hole the skin. After excision of the lesion, the flap was replaced with interrupted stitches of silk in the galea and in the skin.

CASE REPORTS

Case 1.—*Laceration of the scalp sustained in 1932. No symptoms until 1943 when large veins were noted on scalp and forehead. Preliminary ligation of right superficial temporal artery. Excision of cirsoid aneurysm on April 12, 1944. Recovery.*

A   B

FIG. 2.—Case 1: A. Preoperative appearance of the lesion.
B. Appearance after extirpation of the aneurysm.

This 33-year-old soldier sustained a laceration of his scalp in 1932. The wound was sutured soon after injury. His course was uneventful until 1943, when he began to notice increased enlargement of the veins of the anterior region of his scalp and forehead. During this time he was occasionally conscious of "roaring sound" in his right ear. He was admitted to Ashford General Hospital on April 10, 1945.

Examination on admission revealed a small scar in the right parietotemporal region. Near this there was an elevated area 2 cm. in diameter, and from this region three greatly dilated vessels coursed down the scalp (Fig. 2-A). There was a well-defined continuous bruit and thrill over this area, which could be obliterated by occlusion of the right superficial temporal artery. Examination was otherwise normal.

On April 12, 1944, operation was performed. Through a small transverse skin incision the right superficial temporal artery, which was greatly dilated, was ligated and divided just in front of and slightly above the ear. A skin flap, with the base at the top of the skull and its outer margin just inside the hairline, was then turned back (Fig. 2-B). As the incision was made, numerous large arteries and veins were encountered just superficial to the galea. These were controlled by finger pressure until they were isolated and separately ligated and divided. The main mass of vessels comprising the aneurysm was then dissected free from the underlying galea (Fig. 3). The galea and skin were replaced

with interrupted sutures of silk. His recovery was without event and he was returned to duty.

Examination one year later showed no evidence of recurrence.

Case 2.—*Scalp wound from small shell fragment June 20, 1944. In January, 1945 patient first noticed swelling in the right temporal region with headaches and throbbing sensation in the right side of the scalp. Ligation of right superficial temporal artery. Excision of cirsoid aneurysm of scalp on April 10, 1945. Recovery.*
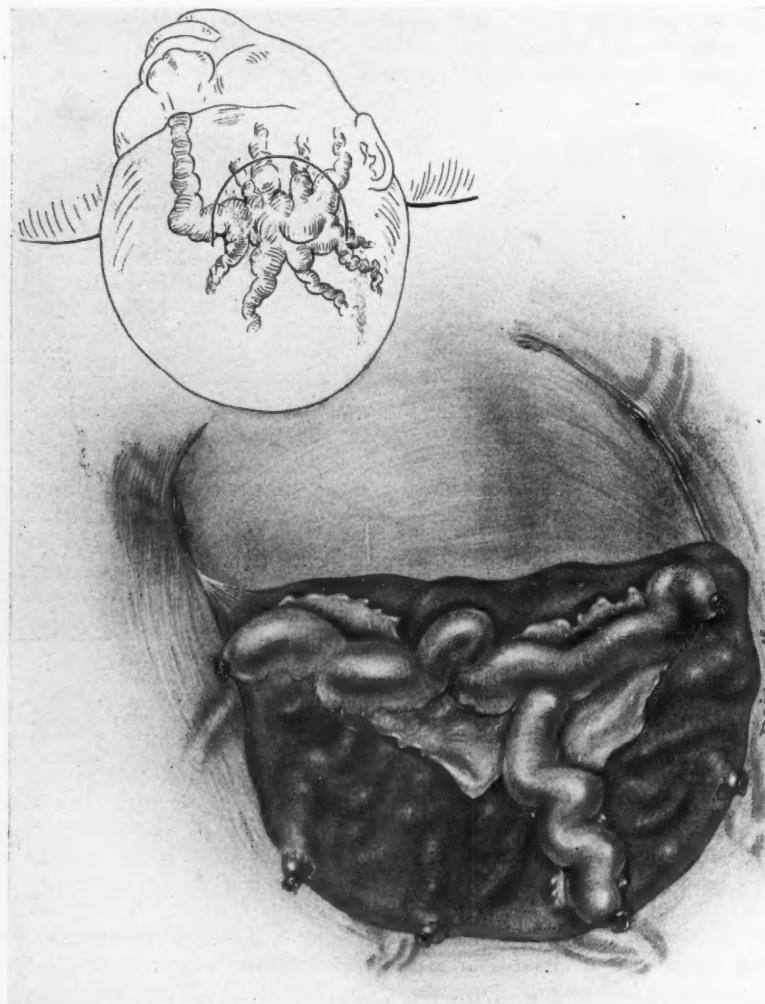
Fɪɢ. 3.—Case I: Operative sketch. The flap has been turned back; the galea opened exposing the aneurysm.

This 27-year-old soldier was wounded on June 20, 1944, by a small fragment from a high explosive shell. There was only slight bleeding and he continued on duty. Due to another wound he entered the hospital on January 10, 1945, and at that time he noticed progressive headaches with a throbbing sensation in the right temporal region. At the same time he noted a pulsating mass just above the right ear. He was admitted to Ashford General Hospital on March 31, 1945.

On examination, no scar could be found in the scalp. There was a pulsating dilatation in the region of the right temple (Fig. 4-A). A definite thrill and a continuous machine-like bruit, accentuated in systole, could be heard in this region. Both the bruit and thrill could be obliterated by occlusion of the right superficial temporal artery. With this obliteration the pulse rate fell from 88 to 80 per minute. Physical examination was otherwise normal.

On April 10, 1945, operation was performed. Through a small longitudinal incision just in front of the upper portion of the ear the superficial temporal artery, which was greatly dilated, was ligated and divided. A skin flap including the galea, with its base just above the ear was then turned down (Fig. 4-B). Numerous dilated vessels were isolated, ligated and divided as the incision was made. The vessels within this flap were then dissected from the tissue between the galea and the skin, and completely removed (Fig. 5). The flap was replaced with interrupted sutures in the galea and the skin.

His recovery was uneventful and two months later there was no evidence of recurrence.

A   B

Fig. 4.—Case 2: A. Appearance of the lesion before operation.
B. Postoperative photograph showing incision.

Case 3.—*Scalp injury without laceration in 1937 followed by a small pulsating tumor. No increase in size of lesion for eight years until a second injury without laceration was sustained over tumor mass. Immediate increase in size of tumor with appearance of large dilated vessels over the scalp. Ligation right external carotid artery, left occipital artery, left superficial temporal artery and resection of cirsoid aneurysm on May 8, 1945. Recovery.*

This 25-year-old soldier suffered an injury to the right parietal region in 1937, when he was struck on the head by a fist during an altercation. Following this a small pulsating hematoma, 0.5 cm. in diameter, developed which gave him no trouble. On March 12, 1945 while in combat training he was accidentally struck on the right side of his scalp by the elbow of his opponent. Three hours later he noticed that the mass was considerably increased in size, although it was not painful or tender. Within the next month the swelling increased rapidly and he became conscious of a discomforting pulsation in his
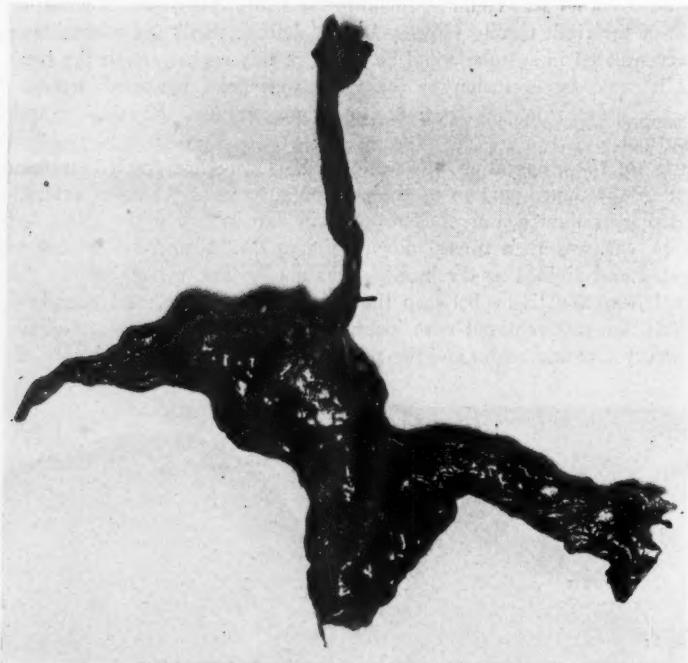
FIG. 5.—Case 2: A portion of the vessels removed at operation.

A   B   C
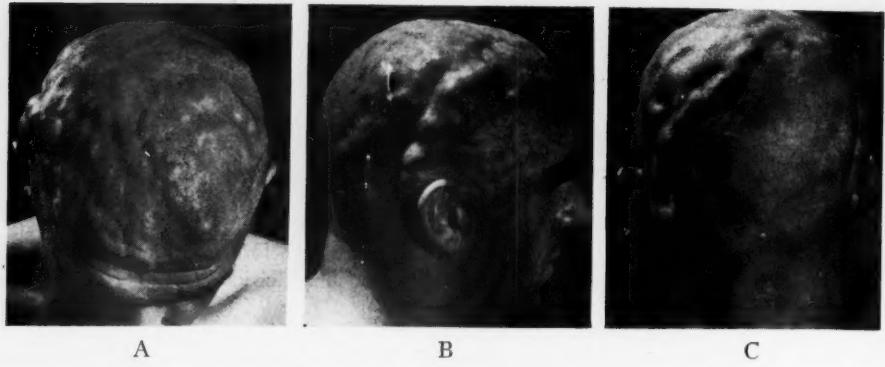
FIG. 6.—Case 3: (A, B, C.) Condition before operation, May 8, 1945.

scalp, and a throbbing, buzzing sensation in his left ear. He was admitted to Ashford
General Hospital on April 23, 1945.

On examination, a large tortuous system of convoluted blood vessels covered the
whole right side of his scalp (Fig. 6-A, B). The main tumor mass was centered in the
right parietal region and the vessels which radiated to and from it were apparently
derived mainly from both superficial temporal, frontal, and the left occipital veins and
arteries (Fig. 6-C). From the central tumor in the right parietal region vessels radiated
over the entire scalp. These appeared to be venous and were readily compressible, although
all of them pulsated. Over the right parietal region a harsh, continuous bruit and the

thrill could be heard. The bruit was transmitted throughout the scalp but was readily obliterated by pressure of the right carotid vessels in the neck.

Operation was performed on May 8, 1945. Preliminary to excision of the aneurysm the right external carotid artery was ligated and the left occipital and left superficial temporal arteries were ligated and divided. A horseshoe-shaped incision, with its base
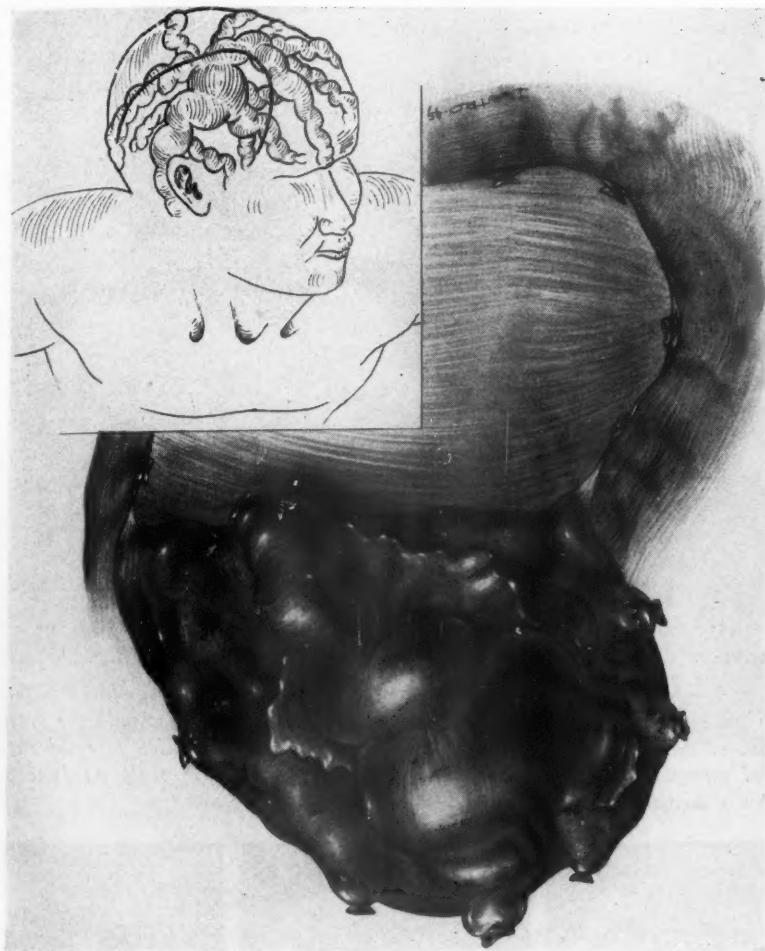

FIG. 7-A

FIG. 7.—Case 3: (A) Operative sketch showing incision of galea and extirpation of aneurysm.

above the right ear, was then turned downward (Fig. 8). The incision was carried through the galea and numerous large tortuous vessels were ligated and divided as they were reached. The galea was then opened and a mass of dilated vessels removed from the underside of the flap (Fig. 7). In spite of previous ligations there was considerable bleeding during the operation which was controlled by sutures and coagulation. The flap was replaced by suturing the galea and skin with interrupted sutures of silk.
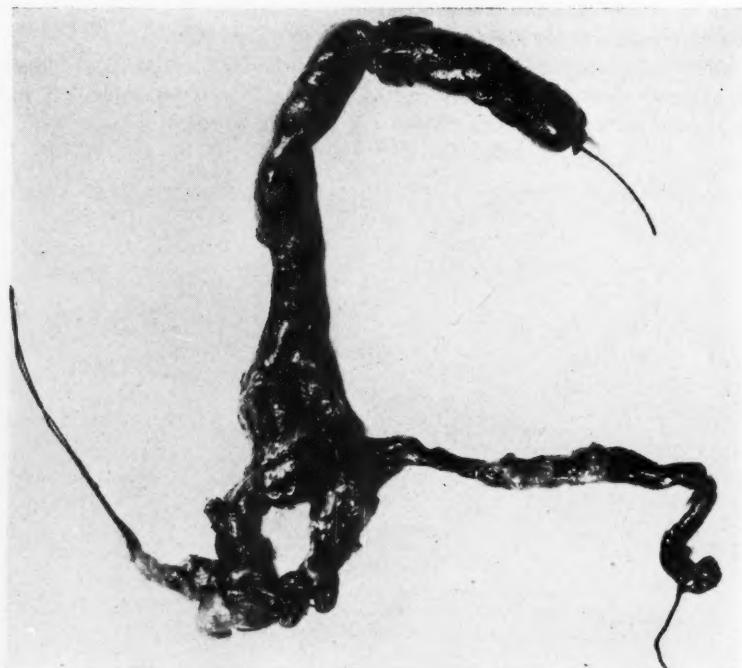
FIG. 7-B

FIG. 7.—(B) Portion of the vessels removed.

Recovery was uneventful and three months after operation there was no evidence of recurrence.

Case 4.—*Congenital nevus of right ear noted for ten years. Discomfort and throbbing in the right side of the scalp first noticed in February, 1945, together with the presence of large dilated vessels. Progressive enlargement of right ear. Ligation of right superficial temporal artery. Excision of cirsoid aneurysm of right side of scalp on June 8, 1945. Excision of hemangioma of right ear on July 14, 1945. Recoovery.*

A   B   C
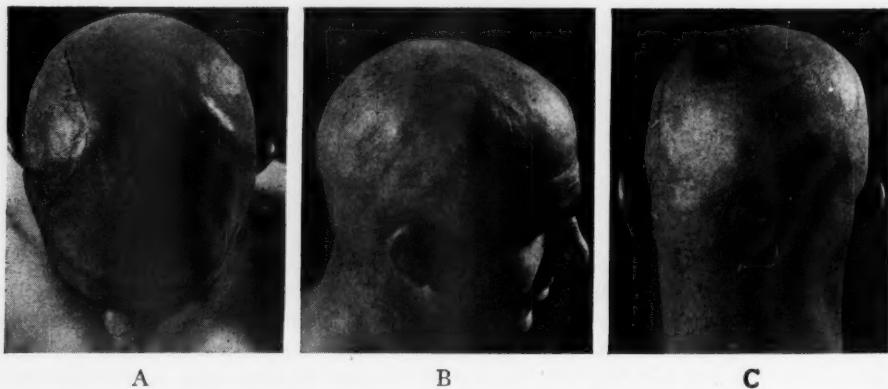
FIG. 8.—Case 3: (A, B, C)—The head has been shaved to show appearance two months after operation. The dilated vessel in the parietal region is thrombosed.

CIRSOID ANEURYSM OF SCALP

This 20-year-old soldier recalled that his right ear had been larger than the left for the past ten years and that it had always been warmer and darker in color than the opposite ear. He was inducted into the Army in May, 1943, but it was not until February, 1945 that he became aware of discomfort and throbbing of the right side of his forehead particularly when wearing a helmet. At this time he first noticed the presence of large dilated vessels above the right ear and the apparent increase in the size of the ear. There was no history of injury except that which could possibly be attributed to the wearing of a helmet. For this he was admitted to Ashford General Hospital on April 28, 1945.

On examination, there was a marked asymmetry of the ears. The left was normal, but the right was considerably enlarged. The soft tissues were thickened and were of a

A   B
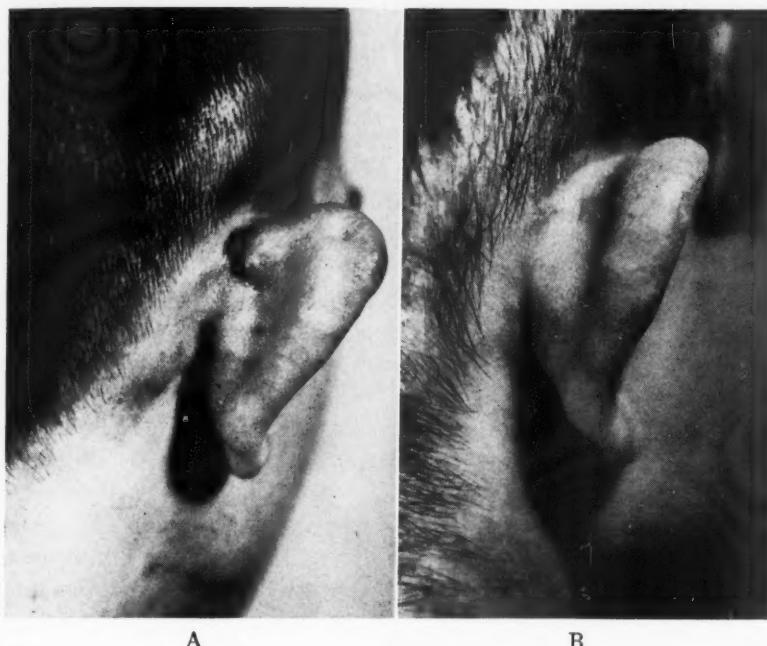
FIG. 9.—Case 4: (A) Appearance of the lesion before operation.
(B) Appearance one month after operation.

deep purplish-blue color. The inner side of the ear showed a considerable degree of fine telangiectasia. On the upper rim of the ear there was a definite "port-wine" discoloration with a number of small and large dilated vessels passing from this region to the right side of the scalp where there were numerous large, tortuous and dilated vessels. These apparently communicated directly with those of the ear (Fig. 9-A). Upon lowering the head the veins over the whole side of the scalp became greatly dilated. The mass of vessels above the right ear pulsated faintly and over them a continuous bruit, accentuated in systole, and of moderate intensity could be heard. The bruit and thrill could be obliterated by pressure over the right carotid vessels. It was believed that this cirsoid aneursym of the scalp originated primarily from a congenital nevus of the ear upon which continuous, although light, trauma had been superimposed.

Operation was performed in two stages. On June 8, 1944 the cirsoid aneurysm of the scalp was removed. The superficial temporal artery and vein were ligated and divided as a preliminary step in the procedure. A horseshoe-shaped flap of scalp including the galea was turned down with the base placed just above the ear (Fig. 9-B). Numerous dilated

vessels were ligated and divided in making the incision. The galea was then opened and beneath it a large number of tortuous vessels were removed. The galea and skin were replaced with interrupted sutures of silk.

On July 14, 1945 the hemangioma of the ear was removed. An elliptical incision made just outside the hemangioma was carried down to the cartilage and all tissue discolored by the hemangiomatous mass was removed. One large communicating vessel from the scalp was ligated and divided. The skin on the posterior aspect of the ear was mobilized, which permitted closure of the skin (Fig. 9-B). Hemostasis was obtained by hot compresses and coagulation. The skin was closed without tension with interrupted sutures of silk.

He recovered from the operation without difficulty, and three months later there was no evidence of recurrence.

REFERENCE

[1] Müller, H.: Ein Fall von arteriellem Rankenangiom des Kopfes. Beitr. z. klin. Chir., **8,** 79-91, 1891.

rgery
1946

and
vere

nade
ored
the
zed,
om-
ures

was

nir.,

THE MANAGEMENT OF ANEURYSMS OF THE LOWER EXTREMITIES*

GEORGE D. LILLY, M.D.

MIAMI, FLORIDA

ARTERIAL ANEURYSMS of the lower extremities are frequent complications of arteriosclerosis. Theis [1, 2] has shown that arteriosclerotic aneurysms of the popliteal artery cause claudication and other symptoms of arterial circulatory insufficiency, and undoubtedly many of the circulatory complaints of arteriosclerotics which are attributed to "hardening of the arteries" are actually caused by popliteal aneurysms which are not detected by the attending physician. When the arteriosclerotic individual develops symptoms of inadequate blood supply to the lower extremities, a careful examination of the femoral and popliteal arteries should be conducted. Simple palpation will reveal an aneurysm in many incidences, but in others the oscillometric tests described by Theis[1, 2] will detect arterial aneurysms which can not be palpated. The detection of such aneurysms is extremely important, because they represent the first step towards the development of much more serious complications. Hufnagel[3] has commented that "all aneurysms are progressive in nature, and, if untreated, lead to disaster." Theis[2] is of the opinion that "injudicious conservative treatment will prolong the disability and increase the danger of thrombosis and the possibility of the thrombus extending into the collateral vessels, with resulting gangrene." Keynes and Morel[4] have pointed out that many small popliteal aneurysms are overlooked, both at the examining table and at the autopsy table. They feel that such undetected aneurysms constitute a special danger, because motion of the knee dislodges clots from them and causes spontaneous gangrene.

As the atheromatous process develops, the popliteal artery is constantly subjected to the trauma caused by bending the knee, and, as a result of these repeated angulations, the diseased intima is ruptured, medial degeneration occurs, and an aneurysm develops. If such an aneurysm is neglected, sudden blockage of the popliteal and anterior tibial arteries will occur at an unpredictable time. Blakemore[5] has emphasized the fact that the possibility of gangrene is ever present, because of the danger of thrombosis or rupture of the aneurysm. Wells, Coburn and Walker[6] have stressed the "near hopeless" outlook in the untreated case of popliteal aneurysm, and have urged that such lesions be repaired before complications develop. Flemming[7] advocates elective surgery upon proven cases of popliteal aneurysms, because he believes the chances of survival of the extremity are much better under these conditions than when spontaneous occlusion occurs.

According to Arnold Henry,[8] during the third century, A. D., a Roman

---

surgeon named Antyllus, described his method of tying the artery above and below the aneurysmal sac, opening it and packing the empty cavity. Since that time various surgical approaches have been advocated for the treatment of arterial aneurysms. (Power[9] credits Richard Wiseman with having successfully ligated two ruptured popliteal aneurysms in elderly individuals during 1672, one hundred years before the classical work of John Hunter.[10])

In 1888, Matas[11] performed the first endo-aneurysmorrhaphy, and his procedure has been accepted as standard technic since that time. The Matas obliterative endo-aneurysmorrhaphy is still the procedure of choice in carrying out the surgical treatment of arteriosclerotic aneurysms of the popliteal artery. The results which he has reported[12] probably never will be excelled. In his series of 103 cases of aneurysm of the popliteal artery operated upon by this technic, 93.6 per cent recovered with good function; there was one death, and only six cases of gangrene. These brilliant results are attributable to Doctor Matas' zeal and patience in laboriously building up a collateral circulation capable of supplying an adequate amount of blood to the extremity before surgery was undertaken. He accomplished this by the use of his special clamp, with which he applied intermittent occlusive pressure to the artery above the aneurysm. Doctor Matas always emphasized the importance of preparing these cases for surgery by patiently developing an adequate collateral blood supply. He has placed great stress upon the importance of conducting careful examinations to make sure that collateral blood supply was adequate before surgery was undertaken.

Keith and Horton[13] made a study of intermittent claudication associated with arteriosclerotic lesions, and came to the conclusion that "from the clinical and therapeutic standpoint, the chief problem involved in this type of case is to build up an adequate collateral circulation in the involved extremity as fast as is possible." They concluded that "any measure which will produce vasodilatation is worthy of trial."

Mulvihill and Harvey[14] experimented upon dogs, and showed that the fall in temperature caused by the ligation of the femoral artery could be avoided by performing a sympathectomy as a preliminary procedure. Theis[15] also carried out experiments upon dogs, and proved the value of sympathectomy as a procedure to improve the blood supply of an extremity. Flothow[16] reported 12 cases of elderly arteriosclerotic individuals with vascular insufficiency, whose circulation was materially benefited by alcoholic injection of the lumbar sympathetic trunk on the involved side. He was able to increase the temperature of the involved extremity by as much as 8° C. by interrupting the sympathetic nerve supply. Lilly[17] has reported similar experiences.

In 1933, Gage[18] first applied this knowledge to the treatment of aneurysms. He performed a right lumbar sympathetic ganglionectomy upon a patient who had a large, mycotic aneurysm of the right common iliac artery, and subsequently he was able to ligate the common iliac artery with no evidence of impaired circulation. In 1934, Bird[19] applied the same principle in the surgical treatment of an arteriosclerotic popliteal aneurysm, with equally gratifying

results. He attributed Doctor Matas' excellent results to his careful building up of a collateral circulation by using the Matas mechanical compressor. He felt that the use of this compressor involved some risk, because of the danger of creating an emergency by rupturing a diseased vessel. For this reason, and because the use of the Matas clamp required a long period of preoperative preparation, he advocated the employment of sympathetic ganglionectomy as a means of developing a collateral circulation safely and quickly. In 1939, Leriche and Froehlich[20] performed a right lumbar sympathetic ganglionectomy because of an occluded aneurysm of the femoral artery; they reported excellent results. In 1940, Gage[21] reported 15 cases of aneurysmorrhaphy done at the Tulane Clinic; preliminary sympathectomy was done in all of these and all of them were successful. In 1942, Richards and Learmonth[22] performed a right lumbar sympathectomy upon a patient with a popliteal aneurysm. Five days later the aneurysm was excised, and postoperatively the foot on the involved side was warmer than the other one. In 1943, Gage[23] in discussing the management of traumatic arterial aneurysms, advocated performing a sympathectomy to develop collateral circulation before obliterating a major vessel. He gave the following reasons for advocating this procedure: Vasospasm is overcome; vasodilatation is obtained; the capillary blood volume flow is increased; blood flow is increased in the distal segment of the artery; the caliber of the vaso varosum is increased; lymphatic flow is increased, and gangrene is prevented. He concluded that sympathectomy was more advantageous than the Matas' clamp because of the speed and thoroughness with which collateral circulation could be developed by sympathectomy.

The following cases are reported to show the value of sympathetic interruption as a method of establishing collateral circulation before undertaking surgery upon aneurysms of the lower extremity:

Case 1.—No. 1235: This 70-year-old white male had been aware of a pulsating mass behind the right knee for three years. He had called it to the attention of his family physician, who advised him that it was nothing serious and to forget it. One morning he spent about 30 minutes squatting on his haunches, working on the motor of his refrigerator; when he attempted to stand he experienced an excruciating pain in the right calf and foot. He could not stand and had to hop to his bed. Subsequently, he spent several hours massaging the foot and calf. Six hours after the injury he called a surgeon, who found a cold, wax-like limb, and amputated in the mid thigh. Postoperative examination of the amputated limb showed a large, arteriosclerotic aneurysm filled with a recent clot which extended down to the ankle and up to the site of amputation.

This case is presented as being typical of the usual course of arteriosclerotic popliteal aneurysms. Had this man been operated upon prior to his accident, there would have been an excellent chance of saving his limb. He now is developing a similar lesion in his remaining limb, and plans have been made to perform a sympathectomy and endo-aneurysmorrhaphy.

Case 2.—No. 1061: This 72-year-old man first presented himself on April 4, 1944, with a cold, painful, numb right lower extremity. For seven years he had noticed an orange-sized, pulsating mass behind his right knee. His medical doctor had told him that this was a normal condition and nothing to worry about. For two years he had

noticed the same type of lesion back of his left knee. For the past four months he had experienced cramps in the right calf muscles when he walked for more than a block. The day before he sought medical aid he went fishing and rowed a boat; he braced his feet on the seat in front of him and rowed with his knees in hyperextension for 30 minutes, and he then experienced a severe pain in the right calf. Shortly thereafter he observed that his foot had become cold and white. The extremity would not support his weight, and became numb. His physician injected morphine and applied heat. The condition persisted through the night, and the following morning the great toe had a purplish hue. He was hospitalized. Examination revealed a tender, hard, nonpulsating mass about 10 cm. in diameter, situated back of the right knee. A pulsating aneurysm of equal size was encountered in the left popliteal space. Two cubic centimeters of alcohol was injected paravertebrally into the proximity of the lumbar sympathetic trunk at the level of the first, second, third and fourth lumbar spinous processes, according to a technic previously described by us.[24] The color of the extremity improved immediately and the pain was relieved. The next day the patient resumed his normal activities, with no complaint except a localized tenderness over the thrombosed popliteal aneurysm. He has had no further difficulty with the foot. The thrombosed aneurysm has remained hard, and the other aneurysm is growing slowly. He refuses to consider surgery on the left side.

This case is presented as another typical complication of popliteal aneurysm in which it would appear that loss of the limb was avoided by a chemical sectioning of the sympathetic nerve supply to the extremity. Evidently, this man has permanently obliterated his right popliteal artery with an organized thrombus. Such a case has been reported by Hodge.[25]

Case 3.—No. J. 80231: This 46-year-old Negro man came to the Jackson Hospital on December 14, 1944, because of pain and swelling in the upper right thigh. This swelling had begun to develop three days previously, with no history of trauma or infection. Examination showed a tender, pulsating mass in the upper one-third of the right thigh. The right thigh had a circumference of 71 cm., as compared with 52 cm. on the left. The Kahn was 4 plus. The foot and leg were cold, and there was no palpable pulse below the tumor mass. A diagnosis of false aneurysm was made. An alcoholic injection of the right lumbar sympathetic trunk was done, and the aneurysm was operated upon. Several quarts of clotted blood were removed and the femoral artery was found to be ruptured at its bifurcation. The artery was ligated. The foot became warmer than the left one, and in six days the man was walking without difficulty.

Case 4.—No. P. 662: This 67-year-old white male was admitted to the hospital, October 21, 1942, with a painful, numb, cold right lower extremity. Three months previously he had noticed a pulsating mass back of the right knee. His physician advised him not to worry about it. The mass gradually increased in size, and on the afternoon of admission he experienced a sudden, sharp pain in the calf. The foot became white and he was unable to bear his weight upon it. Examination showed a pulsating mass in the right popliteal fossa. A cold, white, pulseless foot with ecchymotic spots on the toes was encountered. It was decided that he had dislodged a clot from the aneurysm which had occluded his popliteal vessel at its bifurcation. An alcoholic injection of the right lumbar sympathetic trunk was done, and immediately the pain was relieved. The temperature and color of the foot improved. Three days later the aneurysm was operated upon. A large, arteriosclerotic aneurysm, partially filled with old and new clots, was encountered. An obliterative type of endo-aneurysmorrhaphy was done. The next day the involved side was much warmer than the other extremity. The patient was allowed to walk on the seventh postoperative day, and has had no difficulty since that time.

Alcoholic injection was used in Cases 3 and 4 because of the urgent need of immediate relief from vasospasm.

Case 5.—No. J. 94497: A 63-year-old colored man was brought to the hospital because of pain and swelling of the left knee. One month prior to admission he first observed swelling back of the left knee. The swelling increased rapidly and the patient found it impossible to extend the knee. Examination revealed a hard, pulsating mass in the left popliteal space, which was quite tender. The circumference of the left knee was 58 cm. The circumference of the right knee was 36 cm. The foot was cold and pulseless. The Kahn was 4 plus. The following day a left lumbar sympathetic ganglionectomy was done. This caused the involved foot to become warmer than the normal one. Two days later the aneurysm was operated upon. A large, false aneurysm was encountered. Three quarts of clotted blood were removed from the popliteal space, and a defect the size of a dime was found in the anterior aspect of the popliteal artery. When this defect was plugged with the finger the artery was found to be patent. It was felt, however, that it would be unwise to attempt to reconstruct this diseased vessel, especially since the vein was firmly adherent to the vessel. The artery and vein were doubly ligated and sectioned. The involved foot remained much warmer than the normal one. The patient walked on the third postoperative day, and went home in one week. He has had no more difficulty.

Four of these five cases were more than 60 years of age. All of them demonstrated marked vasodilatation following sympathectomy, in spite of their advanced arteriosclerosis.

Conclusions: The experiences of the author, as exemplified in the cases reported here, and the experiences of Gage,[14] Bird,[15] Leriche,[16] and Richards[17] would indicate that lumbar sympathetic ganglionectomy will develop adequate collateral circulation in a lower extremity quickly and thoroughly, and will enable one to perform surgery upon aneurysms of the lower extremity with comparative safety.

SUMMARY

Aneurysms of the popliteal artery are a frequent complication of arteriosclerosis. Such aneurysms, when neglected, will ultimately create a surgical emergency, either because of a propagating, occluding thrombus, or because of rupture. These emergencies frequently terminate in amputation. Such undesirable end-results may be avoided; first, by examining carefully all patients who complain of peripheral vascular impairment of the lower extremity, to detect the presence of an aneurysm; second, by performing a lumbar sympathectomy to establish adequate collateral circulation quickly and efficiently; third, by repairing the arterial defect by performing a Matas' obliterative endo-aneurysmorrhaphy.

REFERENCES

1 Theis, F. V.: Popliteal Aneurysms as a Cause of Peripheral Circulatory Disease: With Special Study of Oscillomographs as an Aid to Diagnosis. Surgery, **2**, 327–342, 1937.

2 Theis, F. V.: Peripheral Arterial Aneurysms; Diagnosis, Prognosis, and Treatment. Internat. Clin., **2**, 205–216, June, 1940.

3 Hufnagel, C. J.: Popliteal Aneurysms. Med. Bull. Vet. Admin., **20**, 86–90, July, 1943.

4 Keynes, G. L., and Morel, M. P.: Popliteal Aneurysm. Br. J. Surg., **31**, 155–157, October, 1943.

5 Blakemore, A. H.: Treatment of Aneurysm by Amputation. Surg. Clin. N. Am., **18**, 409–414, April, 1938.

[6] Wells, A. H., Coburn, Ç. E., and Walker, M. A.: Popliteal Aneurysm. J. A. M. A., **106,** 1264, April, 1936.

[7] Flemming, C.: Popliteal Aneurysm. Lancet, **1,** 322-323, February 11, 1939.

[8] Henery, Arnold: Some Surgical Aspects of Aneurysm. Practitioner, **150,** 136-143, March, 1943.

[9] Power, D'Arcy: Two Prehunterian Operations for Aneurysm. Br. J. Surg., **22,** 403-405, January, 1935.

[10] Hunter, John: Popliteal Aneurysm. Lancet, **2,** 480, 1826.

[11] Matas, Rudolph: Aneurisms. Keen's Surgery, **5,** 17-350, W. B. Saunders Co., Philadelphia, 1909.

[12] Matas, Rudolph: Endo-aneurismorrhaphy. S. G. & O., **30,** 456, 1920.

[13] Keith, Norman M., and Horton, B. T.: Intermittent Claudication Associated with Arteriosclerotic Lesions of the Abdominal Aorta. Internat. Clin., **2,** 21-30, 1940.

[14] Mulvihill, D. A., and Harvey, S. C.: Studies in Collateral Circulation: Thermic Changes after Arterial Ligation and Ganglionectomy. J. Clin. Invest., **10,** 423-429, August, 1931.

[15] Theis, F. V.: Effect of Sympathetic Neurectomy on the Collateral Arteriole Circulation of the Extremities. S. G. & O., **57,** 737-744, December, 1933.

[16] Flothow, P. G.: Diagnostic and Therapeutic Injections of the Sympathetic Nerves. Am. J. Surg., **14,** 591-604, December, 1931.

[17] Lilly, Geo. D.: Clinic on Peripheral Vascular Disease of the Lower Extremities. Jackson Hospital Bull. (Miami), **2,** 28-32, 1940.

[18] Gage, I. M.: Mycotic Aneurysm of the Common Iliac Artery. Am. J. Surg., **24,** 667-710, 1934.

[19] Bird, C. E.: Sympathectomy as a Preliminary to the Obliteration of Popliteal Aneurysms. S. G. & O., **60,** 926-929, May, 1935.

[20] Leriche, Rene, and Froehlich, Fritz: Gangrene in Obliterated Aneurysms of the Limbs. La Presse Medicale, **47,** 1625, December 19, 1939.

[21] Gage, I. M.: The Development of the Collateral Circulation in Peripheral Arterial Aneurysms by Sympathetic Block. Surgery, **7,** 792-795, 1940.

[22] Richards, R. L., and Learmonth, J. R.: Lumbar Sympathectomy in the Treatment of Popliteal Aneurysms. Lancet, **242,** 383-384, March 28, 1942.

[23] Gage, I. M.: Traumatic Arterial Aneurysms of the Peripheral Arteries. Am. J. Surg., **59,** 210-231, February, 1943.

[24] Lilly, Geo. D.: Alcohol Injection of Lumbar Sympathetic Trunk. J. A. M. A., **128,** 479-481, June 16, 1945.

[25] Hodge, Lenox: Spontaneous Cure of a Popliteal Aneurysm. Am. J. Med. Sc., **40,** 420, 1860.

DISCUSSION.—DR. AMBROSE H. STORCK, New Orleans, La.: Some experiences at the Vascular Center at DeWitt General Hospital have a close bearing on several of the subjects just presented. I am sorry that Major Norman Freeman, Chief of the Vascular Section at DeWitt, could not be here to take part in this discussion.

In connection with the management of popliteal aneurysms presented by Doctor Lilly, the frequent possibility of successful restoration of the popliteal artery in operations for popliteal arteriovenous fistulae was demonstrated at the DeWitt Vascular Center. Repair of the popliteal artery was done in eight cases and was successful in six. Incidentally, in a series of 88 arteriovenous fistulas in various parts of the body, restoration was done in 21 instances, with failure in only three. Postoperative arteriograms were done to demonstrate patency.

A lateral approach to the popliteal artery, modeled after that used by Doctor Elkin for the exposure of the popliteal and tibial vessels, was used to advantage in several instances, either for the purpose of controlling the popliteal artery preliminary to its exposure by conventional posterior incisions or as the sole method of approach to popliteal arteriovenous fistulae. The advantage of the lateral approach is that it makes exposure

of the popliteal artery easier, particularly when the posteriorly overlying popliteal vein is large or is surrounded by scar tissue. In the restoration of arteries and veins in general, transverse or oblique suture is definitely superior to longitudinal suture, which latter reduces the diameter of the vessels. No anticoagulant therapy was employed in any of the restorative operations. Whenever possible, the accompanying vein was restored as well as the artery involved. The incidence of edema and easy fatiguability was found to be less when the vein was restored. Because of the observation that the performance of sympathectomy in conjunction with operations for aneurysms and arteriovenous fistulae led to functionally better results, it was increasingly customary to perform preliminary, simultaneous, or follow-up sympathectomies.

The rapid increase in size and surface extent following trauma to a cirsoid aneurysm, as reported by Doctor Elkin, was likewise observed in one of our cases, a soldier who, while a prisoner of war, received a blow on an ear which was the site of a small cirsoid aneurysm. Following the trauma there was rapid local increase in size of the lesion with spread to the scalp, mastoid region, and upper neck.

Doctor Pemberton's report on the successful repair of an aorta-vena cava fistula is paralleled by a quite similar case operated upon recently by Major Norman Freeman and me.

Case Report.—A 25-year-old soldier received a right upper abdominal and a spinal cord shrapnel wound on Okinawa on May 14, 1945. He was immediately paralyzed from the waist down. Celiotomy on the day of injury disclosed a large retroperitoneal hematoma. Thrombophlebitis of the right leg followed operation. Six weeks after injury a pulsating mass, with intense thrill, was noted in the upper abdomen. Studies at the time of admission to DeWitt General Hospital showed some evidence of renal impairment and greatly dilated veins over the abdomen. Cardiac examination showed minimal damage. Because of increase in size of the aneurysm and the development of gastrointestinal symptoms including vomiting, operation was unquestionably necessary and was performed on September 27, 1945.

OPERATION.—A right paramedian incision was made from the xiphoid to just below the umbilicus. On opening the peritoneum a large pulsating mass was found beneath the gastro-hepatic omentum. An attempt was made to visualize the vessels entering the pulsating mass by division of the gastrohepatic omentum, starting from the left and working toward the right. The common, cystic, and hepatic ducts were pushed forward by the pulsating mass which occupied the posterior right upper abdominal quadrant, extending from the diaphragm, across the midline, down over the surface of the right kidney and lateralward to the edge of the liver. Pressure within the mass was considerable, and at a point close to the gallbladder, where the thrill was most intense, digital compression caused cessation of the thrill. Pressure on the aorta just below the diaphragm obliterated the bruit and thrill and caused the sac to collapse. Even after practically complete division of the gastrohepatic omentum it was still impossible to visualize satisfactorily the exact extent and components of the arteriovenous fistula. A rubber catheter was placed around the aorta just below the diaphragm and fitted to a Bethune tourniquet. Since it was impossible to localize the point of communication between the aorta and the sac, the peritoneum and transversalis fascia were incised from within the abdomen just lateral to the midline anteriorly, and the transversalis fascia and peritoneum were reflected out of the left lumbar gutter. By this procedure the descending colon, the pancreas, the left kidney and the small intestine were reflected to the right. The retroperitoneal tissues over the lumbar vertebrae were thickened and edematous, with some discoloration of old hemorrhage. The aorta was again encircled by a piece of rubber tubing proximal to the origin of the left renal artery. With the proximal and distal aorta occluded and by careful dissection with scissors, the junction of the aorta with the sac was finally exposed and the aorta was then cut away from the sac at this location and the opening into the sac was digitally plugged. The opening in the aorta was about one-half inch in length and was closed by two running sutures. The vena cava distal to the sac appeared to be obliterated. The opening in the sac was closed with a running suture. The rubber tubing which had been placed around the distal aorta, the left renal artery and the proximal aorta was released, and a good pulsation was transmitted across the aortic suture line. There was no leakage. Two Penrose drains were inserted through a stab wound below the left costal margin, one extending to the space beneath the diaphragm and the other

down to the region just above the pelvis. The peritoneum was closed with interrupted No. 20 cotton and the rectus fascia was closed with interrupted steel wire sutures. The skin was closed with silk. During the operation the patient lost considerable blood and was given 3,000 cc. of blood and 2,000 cc. of glucose and normal saline. At the conclusion of the operation, which lasted for eight hours, the patient was in fairly good condition and within one hour the extremities were warm and pulses were easily palpable at the wrists.

Convalescence was stormy because of impaired kidney function for the first two weeks following operation. Good recovery, however, finally took place and the patient is up and about within the limits imposed by his spinal cord injury. The dilated abdominal veins which were present before operation have disappeared.

DR. CLARENCE E. GARDNER, JR., Durham, N. C.: In discussing Colonel DeBakey's paper I should like to report our experience with acute artery injuries in a General Hospital in England. These injuries were received by crew members of heavy bombers of the Eighth Air Force while on high altitude bombing missions over Germany. They were received in the hospital on an average of six hours after being wounded; it was usually an additional two hours before they came to the operating room.

During the course of one year we treated 863 wounds in 645 fresh Air Corps casualties. They were distributed as follows:

	Per Cent of Total	No. of Wounds	Complicated Wounds
Head and neck	20%	173	25 cranial penetrations 3 artery wounds, face and neck.
Trunk	11%	96	41 pleural or peritoneal penetration
Extremities	69%	594	32 major artery wounds (5.4%) 48 peripheral nerve (8.0%) 183 compound fractures (21.2%)

There were 35 major arterial wounds, distributed as follows:

			Amputation	
Number	Ligated	Sutured	Immediate	Delayed
1 Common carotid		x		
1 Internal maxillary	x			
1 Costocervical trunk	x			
1 Subclavian (mediastinal)	x			
2 Brachial (upper 3)	x			
1 Brachial (at elbow)	x			
2 Radial and ulnar		x	x	
1 External iliac	x			x
6 Femoral	x			x gas gangrene
	x			
		x		
			x	
			x	
			x	
2 Profundus femoral	x			
5 Popliteal	x			x gas gangrene
		x		x
		x		x
			x	
			x	
9 Posterior tibial	x			
3 Peroneal	x			
Total....35	24	5	6	5

Of the 35 injured arteries 24 were ligated, five were sutured and, in six, attendant damage to the extremity was so severe that immediate amputation had to be done.

In five cases gangrene subsequently developed and amputation was necessary; in

two cases because of development of gas gangrene. Incidentally, these were the only two cases of gas gangrene we saw, although we grew organisms of the clostridial group in 42 per cent of 177 cases in which freshly débrided tissues were cultured.

Gangrene of the foot developed in the one external iliac artery which was ligated and in the two popliteal arteries which were sutured.

From this experience we might conclude that under battle conditions ligation of most of the major arteries is a satisfactory procedure. However, in certain locations, notably in the popliteal and common femoral, possibly also in the brachial above the deep branch, some form of restitution of blood flow within the artery should be devised. In our cases the sutures seemed satisfactory except in the two instances of repair of the popliteal artery. Failure might be attributed to the fact that heparin was not available in either of these cases, or to the method used (Doctor Blakemore's vitallium tubes were not available), or to the fact that the time interval between wounding and surgery was too long in each case.

DR. BARNEY BROOKS, Nashville, Tenn.: There is too much experimental and clinical evidence for the possible beneficial effects of ligation of the concomitant vein in certain instances of arterial obstruction for this procedure to be discarded as unworthy of consideration. Any worth while evidence for or against the value of this procedure would have to be composed of a considerable number of instances, in each of which there was ample opportunity for a sufficiently careful analysis of the conditions to be sure that each instance was one suitable for test. I have previously emphasized that an occasion for a therapeutic venous occlusion for the prevention of gangrene is seldom encountered.

LT. COL. F. A. SIMEONE, Washington, D. C.: I should like to close this discussion by presenting a little more of an analysis of the factors affecting the results of the acute wounds of the arteries.

This slide indicates the results of attempts to aid the circulation by means of sympathetic block and sympathectomy. The incidence of amputation after sympathectomy was 71.4 per cent in 42 cases. After sympathetic block without sympathectomy, the incidence of amputation was 48.8 per cent. The figures suggest that sympathetic block improves the results while sympathectomy makes them worse. Actual experience with these cases provides a ready explanation for this paradox. Sympathectomy was done in relatively few cases of arterial injury. Indeed, it was often done only as a "last resort" when survival of the limb was thought to be unlikely—hence, the bad results. Sympathetic block, on the other hand, was done more often as a routine procedure after acute wounds of the arteries and the results are better.

This next slide shows the better results when the lesions were repaired by simple suture than when continuity of the vessel was reëstablished by nonsuture methods. The results after nonsuture anastomosis are similar to those for the group as a whole. Better than average results can be expected after simple suture because cases in which this is possible usually have small wounds with little tissue destruction. Wounds for which a nonsuture type of anastomosis was necessary in order to bridge the gap in the artery were generally very extensive.

The next slide shows the effect of the time-lag from wounding to surgery upon the results of arterial injuries. The importance of this factor is obvious. The majority of cases were not operated upon until 12 or 15 hours had elapsed from the time of wounding and thrombosis may have occurred in the peripheral vessels. This fact, along with the extensiveness of the wounds, imposed serious limitations upon the practice of nonsuture anastomosis.

PLASTIC SURGERY IN WORLD WAR I AND IN WORLD WAR II*

JOHN STAIGE DAVIS, M.D.
BALTIMORE, MD.

As there are a large number of men, wounded or injured, in World War II, who require plastic and reconstructive surgery, it may be timely to look into what is being done for these patients, and also to compare the present set-up with that used for the treatment of similar cases in World War I. As I am more familiar with plastic surgery in the army, my observations will be based principally on that service.

The object of military plastic surgery is primarily the restoration of function and comfort, and incidentally with the improvement of appearance.

When we entered World War I, there was total ignorance of plastic surgery in the army, but it must be said, that even in civil hospitals and medical schools of that time, 1917, the appreciation of this branch of surgery as a special subject was also totally lacking.

The tables of organization in the army failed utterly to make adequate provision for plastic surgery in World War I and repeated in World War II. Unquestionably, the first world war awakened general interest in the possibilities of plastic surgery, but few additions were made during this period to the basic principles of plastic surgery, which had been established long years before, although some of them were rediscovered and reported as new. As a matter of fact, there have not been any important new principles in plastic surgery developed so far in World War II, but simply better and more skillful use has been made of methods and principles previously devised.

In England, when the unexpectedly great number of maxillofacial wounds began to come in, in 1914, there was no one trained to take over these cases, as their ignorance of the importance of the subject was at that time as profound as ours, when we entered the war. In this emergency, Harold H. Gilles, an otolaryngologist, was assigned to this work, although he had not had any previous experience in plastic surgery. He collected a group of men around him, including dental surgeons, and at first, by trial and error, the wounded men were treated. Later, as experience developed, the maxillofacial cases to which his service was limited were segregated, because of the insistence of Sir Arbuthnot Lane, in a hospital at Sidcup, and splendid work was done. After our entry into World War I, a number of American medical officers, recruited from civil life, worked temporarily with Gilles at Sidcup and obtained valuable additional experience. Full advantage was taken of the knowledge thus gained, and our own wounded, requiring plastic reconstruction of the maxillofacial region, received in consequence excellent care when they began to appear for treatment. Several U. S. Army Centers were set up in France to which max-

---

illofacial cases were supposed to be sent. One of these was Base Hospital 115 at Vichy, another was in Paris and a third was in Bordeaux. My impression is that these centers were largely used in preparing cases for evacuation to the United States, and that little or no definitive work was done in them. These patients were eventually sent either to General Hospital No. 11, at Cape May, N. J., or to General Hospital No. 2, at Fort McHenry, Baltimore, or to the Walter Reed Hospital, or to General Hospital No. 40, at St. Louis.

Marked progress was made in World War I in the treatment of fractures of the jaws, and in the repair of destructive wounds of the maxillae, by bone grafting and by adequate and ingenious prostheses, and these methods have stood the test of time and some have been improved upon in World War II.

There was also great opportunity to try autogenous cartilage transplants, and also isocartilage was used when the occasion presented and cartilage was available. The reported results were promising, and after the war, this work in France and England by military surgeons stimulated again further investigation of the use of autografts and also of isocartilage, both fresh and preserved. Other tissues such as fascia, fat, periosteum, mucous membrane and nerves were also transplanted when needed.

Probably, the most useful plastic procedure developed during World War I was the tubed-flap which was reported independently by Filatov, in 1916, in Russia and Gilles, in 1917, in England. Another useful procedure reported in 1917 was the Esser "inlay," which is the application of an Ollier-Thiersch skin graft on a dental compound mould to form the lining of a cavity. Some skin grafts and skin flaps were used, but very conservatively, particularly in regard to skin grafts, as compared with their lavish use in World War II.

In World War I, there were no definite regulations as to the treatment of burns, and each surgeon used his own judgment and individual methods. In World War II, on the other hand, a great deal of attention has been given to the treatment of burns, which have been very numerous. I will not go into details here, but will only say that a special committee of the National Research Council has been studying the question, and that much progress has been made, and burns are being better treated now than ever before. However, I do not believe that the final answer has yet been found. The main features in the most modern methods of treatment are the care of shock; the prevention of loss of fluids by nonadherent pressure dressings, infrequently changed; the prevention of infection; the acceleration of healing by skin grafting as early as possible; and adequate nutritional care with proper vitamins, *etc.*, as convalescence develops.

Artificial replacements of chins, noses, ears, eyes, *etc.*, were devised in World War I, and are still being utilized both for permanent use and for the interval periods between operative procedures. Research along this line has been largely done by men in the dental corps and by artists, who are especially skilled in moulding and coloring the various new materials now available.

After World War I, scant interest was taken in plastic surgery by the regular medical corps of the armed services, and there were no surgeons in

either of the services, who were especially trained for, or who showed any special ability to do this work. In fact, there was little official recognition of the scope and necessity of plastic surgery by the Medical Corps of either the army or the navy before we entered World War II, as the tables of organization show.

On the other hand, since World War I, in civil practice, great advances have been made in almost every aspect of the art of plastic surgery, and a voluminous additional literature has appeared. There are better methods of treating and dressing wounds and of combating infection. Improved technics have been developed in skin grafting; in flap shifting; in rotation and use of adjacent tissues, and in the handling and successful use of all transplantable tissues. Shaped cortical and cancellous bone grafts and cancellous bone chips are being frequently utilized in the repair of bone defects. Auto- and iso carved cartilage grafts and diced cartilage for support and filling are being used more freely and successfully than ever before. There is a better understanding of the utilization, in the final repair, of scar or scar-infiltrated tissues; in the use of relaxation incisions, Z-plastics, and gradual partial excisions.

A Subcommittee of the Division of Medical Sciences of the National Research Council on Plastic and Maxillofacial Surgery was appointed,* and considerable study was given to the early care of wounds of the face and jaws by this committee, as it was realized from the experience gained in World War I that skilled early treatment within a few hours, if possible, after the wound was inflicted made a great difference in the length of hospitalization and in the ultimate outcome. In order to facilitate early treatment, officers and men in the medical department in the Combat Zone were supplied with equipment for rendering first aid treatment for maxillofacial injuries and were instructed how to use this equipment—in arresting hemorrhage; providing adequate respiratory air-way; securing temporary approximate reduction and fixation of bone fragments; and also to prepare the patient for safe transportation from the Combat Zone to hospitals in the rear, either in a sitting position or lying on a stretcher face down if there was any danger of obstruction in the air passages. Other points found to be important were: very conservative débridement of the face and hands; avoidance of packing facial wounds open; avoidance of removing any bone fragment with soft-part attachment; insistence on the early closure of facial wounds by men trained to do this work; and the early covering of all extensive denudations by skin grafting or flap shifting.

The first idea about utilization of plastic surgery in World War II was that there should be a large number of plastic and maxillofacial teams made up of a plastic surgeon and a dental surgeon, and that these teams should accompany troops to the Front, where they would give early plastic care to those requiring this service. A number of four- and six-week courses were given in different parts of the country to train men for this work. There were also two

---

* Chairman, Robert H. Ivy; John Staige Davis, Joseph D. Eby, P. C. Lowery, Ferris Smith, Brig. Gen. F. C. Fairbanks, and Col. Roy A. Stout.

or three three-month courses given in different clinics, which were very much better.

After a time, all of these courses were discontinued, as it was realized that most of the real plastic surgery, after early closure of face wounds at Evacuation Hospitals, should be done in the Zone of Interior, and that a comparatively few trained general plastic surgeons in Plastic Centers, with adequate assistants and necessary equipment, could handle the situation much more satisfactorily.

No one in authority had an idea that plastic cases would be nearly as numerous as they have turned out to be in both services, and for that reason, the facilities at first provided turned out to be quite inadequate.

In time, nine Centers in newly built Army General Hospitals have been designated for plastic work in the United States: the Valley Forge General Hospital being the first one assigned for this purpose on March 6, 1943, and the others were added as necessity arose. These are the Newton D. Baker General Hospital, Martinsburg, W. Va.; Wm. Beaumont General Hospital, El Paso, Texas; George W. Crile General Hospital, Cleveland, Ohio; H. D. Cushing General Hospital, Framingham, Mass.; Dibble General Hospital, Menlo Park, Calif.; Northington General Hospital, Tuscaloosa, Ala.; O'Reilly General Hospital, Springfield, Mo.; Valley Forge General Hospital, Phoenixville, Pa.; and Wakeman General Hospital, Camp Atterbury, Ind.

It is impossible to visualize, unless one has seen it, the great number of plastic patients at present in the nine army Plastic Centers in the United States. They run from 1,000 to over 1,700 beds on a single service, plus additional patients from the orthopedic and other surgical services. Many of these patients require multiple operations, and the operative schedule in some of the Centers runs from 18 to 25 each day. Some of these operations are performed under general anesthesia, some under local. All of them are based on the restoration of function, and none of them are of the purely cosmetic type. It is a thrilling and stimulating experience to see some of these Centers in action, and to observe the superb morale of the men and the remarkable results being obtained.

The ability, breadth of training, experience and understanding, and organizing capacity of certain of the Chiefs of the Plastic Service is far greater than that of others, and, in consequence, better planned and better executed plastic surgery is being done in some Centers than in others. It is to be hoped that, in due time, the work in all the Plastic Centers will be equally excellent, and I feel that this can be accomplished by having general plastic surgeons in charge, and by having a thoroughly competent consultant in plastic surgery to supervise all Centers. Then, by the transfer of those unequal to the job and by adequate supervision and proper standardization of basic procedures, the best results can be obtained.

The equipment, operating facilities, number of beds, number of assistants and nurses, *etc.*, is better in some of these Centers than in others, and several of them are badly overcrowded and understaffed. There has been consider-

able difficulty in supplying trained assistants at these Centers, as many men with plastic training have been assigned to other work, and it is not possible under the present organization of the Medical Corps to get them back. Every facility is being used in some of the Centers for graphically recording the wonderful series of plastic cases by moulonges, photographs, movies and drawings. In others, the equipment is poor and little interest is taken.

At the beginning of World War I, there were, with the exception of myself, no general plastic surgeons available in the United States. In France, there was Morestin. In England, no one was trained along this line, but since then the entire picture has changed, and there are now a number of excellent plastic surgeons in this country and in all other civilized countries. There are today very few class "A" medical schools where plastic surgery is not being taught, and also in nearly all great hospitals there are plastic services. The American Board of Plastic Surgery has been organized, and there are two flourishing plastic surgery societies in operation. In consequence, when plastic surgeons were called for in this war, many more trained men were available than there were in World War I.

In World War I, for the first time, sections representing various special fields of medicine and surgery were established in the office of the Surgeon General in Washington, and among these sections were facial-plastic and oral surgery. Major V. P. Blair of St. Louis was called to the Surgeon General's office to organize this service. He was ably assisted by Major Robert H. Ivy, of Philadelphia.

I urged, at that time, that the Division be expanded to include all cases requiring plastic reconstruction regardless of the part of the body on which the lesion might be, but could not put it over, as there was no appreciation of the necessity of general plastic surgery by those with the power to act. I again urged this expansion in World War II, and some progress has been made along this line.

In World War II, in the Surgeon General's office in the Surgical Consultants Division, there have been created branches in general surgery; orthopedic surgery, neurosurgery, ophthalmology, otolaryngology, radiation, transfusion therapy and chemical warfare. It has seemed strange to me that a consultant in plastic surgery was not also added to the list. I, personally, felt that the lack of a representative in the field of plastic surgery in this war, considering the great number of casualties requiring plastic reconstruction, was a mistake. In place of a consultant in uniform, several outstanding general plastic surgeons from civil life were appointed civilian consultants in plastic surgery during the last year of the war. These consultants were Drs. Robert H. Ivy, Jerome P. Webster and John Staige Davis.

An inspection trip was made of all the U. S. Army Plastic Centers by Dr. R. H. Ivy and Dr. J. P. Webster in April and May, 1945, and a very comprehensive report was sent to the Surgeon General with certain well-considered recommendations. Practically, no further use was made of these consultants. I am delighted to be able to say that within the last few weeks a

consultant in plastic surgery has been added to the Consultants Division of the Surgeon General's office. Now, even at this late date, it will be possible to have all Plastic Centers under central observation and direction by an expert.

There are certain army General Hospitals where there is, as there always should be, close coöperation between the plastic surgery section and every other surgical section in the hospital. In other hospitals, this coöperation is not evident, and, in consequence, the most effective care of wounded men cannot be carried out. Every surgical division of the hospital—neurologic, orthopedic, urologic, ophthalmologic, and general, at some time, needs the help of plastic surgery, and plastic surgery needs the help of every other division from time to time, so close coöperation is essential. Section or individual differences must be subordinated in order to give the wounded soldier the skilled care to which he is entitled.

The Dental Corps has an excellent organization, with active consultants, and is doing splendid work in its field. In most of the Plastic Centers, there is close coöperation between the plastic and dental services, and many of the problems of maxillofacial reconstruction are worked out together. The dental service is also invaluable in the construction of prostheses, plates, and various splints. However, it must be remembered that dental surgeons, with few exceptions, are not qualified to perform plastic operations, even on jaws, on account of inadequate general surgical training.

Many orthopedic cases are referred to the Plastic Service for the transplantation of soft-parts to fill defects, before orthopedic procedures can be carried out, and some of the results are astonishing.

In a number of the army Plastic Centers, following Dr. Sterling Bunnell's suggestion and demonstration, hand cases requiring reconstruction have been grouped, and under plastic and orthopedic surgeons assigned especially to this phase of the work, very gratifying results are being obtained, and many hands have been salvaged, and made into useful functioning members, which seemed beyond saving.

In World War I, it was soon found that segregation of the maxillofacial cases in special hospitals or wards was most important psychologically in caring for these mutilated patients, and this should always be done, if possible, and is being done in our army and navy with plastic cases of all kinds.

At the beginning of World War I, there were no books available on the subject of plastic surgery, and although there were chapters in the surgical "Systems," nothing practical was available for the guidance of the military plastic surgeon. Since then, a number of books have been written on the subject and on its various phases. The most recent contribution, written largely by Ferris Smith, is the Manual of Plastic and Maxillofacial Surgery, one of the military surgical manuals, gotten out by the Subcommittee on Plastic and Maxillofacial Surgery of the National Research Council. Another function of this committee, besides getting out the Manual, was to send recommendations to the Surgeon General in regard to improvements in the plastic and maxillofacial set-up in the army and navy. This was done at the early

meetings on several occasions, with absolutely no results. However, things have improved.

One of the most important advances in the care of the wounded in World War II is the rapidity with which they are evacuated from the field to the hospitals where every care can be provided, and this is particularly important in the evacuation of severe burns and severe facial injuries. Sometimes, this can be done by plane in the matter of a few hours, and men are frequently back in the United States within a few days. There are also a number of army hospital ships and trains to facilitate this evacuation.

The free use of plasma in this war has saved many lives, and the daily shipping of whole blood for use in those cases where plasma is insufficient is an added factor of safety to the seriously wounded. All of these advances in treatment are as advantageous to men requiring plastic surgery as they are to other types of wounded.

Vast improvement has been made in the methods of anesthesia, both general and local, since World War I, and these advances have been most helpful in military plastic surgery.

The psychologic handling of plastic patients requiring help along this line is also being very well done in some hospitals and is a potent factor in securing satisfactory end results. In fact, the maintenance of high morale in the plastic wards means everything to each individual man and also to all of the men as a group. Some of the surgeons know how to keep morale high, and in consequence, their general results are better and their wards are happier.

In plastic surgery in this war, as always, asepsis should be aimed at, as often with scant tissue available for the reconstruction, infection may destroy the chance of the desired repair. But in battle wounds, infections frequently follow in spite of every precaution. In these instances, the wounded man today has a much better chance than he had in World War I, as with the local as well as the internal use of the sulfonamides and with the free use of penicillin, infections are prevented, and many cases which would previously have been fatal are saved.

In the European Theater in World War II, the Chief Surgeon, Major General Paul R. Hawley, promptly appointed a full set of consultants, including the specialties. It was foreseen early that a great number of war casualties would require plastic reconstruction, and their care could best be met by central direction. The first consultant was Lt. Col. J. Barrett Brown, whose title was Senior Consultant in Plastic and Maxillofacial Surgery and Burns, and as his assistant, Major Eugene M. Bricker. Together, they visited and studied the British set-up in civil and military plastic surgery. Close association with free interchange of ideas was maintained with both British and American dental surgeons and also with general, orthopedic and neurologic services.

It was difficult to establish plastic surgery as an army specialty, principally because of the lack of plastic surgeons on the tables of organization. However, great progress was made with the full support of the Chief Surgeon.

The duties of the consultant consisted of placing personnel properly;

establishing Plastic Surgery Centers; in determining the extent of plastic surgery to be carried out in the E.T.O.; in controlling, sorting and evaluation of patients so that they would get into the proper hands; and in keeping in touch with the condition of patients when they arrived in the United States from E.T.O. The first Plastic Center in E.T.O. was established in December, 1942, at the 298th General Hospital, and on "D" Day, June 6, 1944, about 18 months later, there were ten functioning Plastic Centers in the United Kingdom where plastic, maxillofacial injuries and burns were treated. The purpose of these Plastic Centers was to treat early, and restore to duty promptly, those with minor injuries, and to evacuate to the United States as soon as possible all those more seriously injured, who could not be returned to duty in from 120 to 180 days.

These Centers were established within easy ambulance haul of the areas into which the patients were evacuated by air, water or hospital train, as it was important to get them into the hands of the plastic surgeons as soon as possible after injury.

On the continent, as the invasion progressed, there were 11 or 12 Plastic Surgery Centers in different hospital groups. Those of particular importance were at Liege and Paris. The one at Liege functioned as a Transit Center for air evacuation of plastic patients to the Centers in the United Kingdom. The two in Paris functioned for air evacuation of patients to the United States.

In the Mediterranean Theater, no permanent Plastic Center was set up. Temporary designations were usually established in one of the General Hospitals. The first one was in the 33rd General Hospital, at Bizerte. During the Italian campaign, there was such a Center, the 52nd Station Hospital, in Naples.

In the Pacific area similar arrangements existed toward the latter part of the war. In those areas throughout the world where special plastic facilities were not available, excellent work was done on plastic and maxillofacial cases by plastic and dental surgeons assigned to this work in different hospital installations, as allowed by the tables of organization.

In England, in World War II, Sir Harold Gillies, with his colleagues, has charge of all plastic surgery, and there are Plastic Centers at Basingstoke, Gloucester, Birmingham, Edinburgh, and probably other places.

All British maxillofacial casualties in the African campaign were segregated in a Center in Algiers, and in Italy a similar Center was set-up in Naples. Remarkably fine work was done on these patients, who were usually received within the first few hours after injury.

Little authentic news about the progress and practice of military plastic surgery in World War II has come as yet from either the Russian Medical Corps, or from the military services of the Axis countries.

In the navy, in World War I, there were not many plastic cases as compared with those in the army, and there was no special service organized for their care. In World War II, the same procedure was followed at first, as it was said that the Surgeon General of the Navy did not see the necessity of

a Plastic Section, and thought that any naval surgeon should be capable of doing plastic work. However, when a considerable number of men requiring real plastic reconstruction began to come in, this misconception was soon rectified, and with the help of a group of naval reserve medical officers, who were skilled plastic surgeons in civil life, several Plastic Centers were organized. In the Center at San Diego, California, under Capt. H. L. D. Kirkham, and his staff, who had been provided with fine equipment, large numbers of sailors and marines requiring plastic work are splendidly cared for. There are several other naval Plastic Centers, where excellent work is also being done, one at the U. S. Naval Hospital at Bethesda, Md.; another at St. Albans, L. I.; and another at the Oak Knoll Naval Hospital, Oakland, California. So the navy has also waked up to the importance of having plastic work done by trained plastic surgeons. In the September 1, 1945, J. A. M. A., the Surgeon General of the Navy reports that there were, during the week of August 22, 1945, a total of 796 plastic surgery patients in all of the naval Plastic Centers. From this, it can be seen that plastic surgery cases in the navy were not nearly as numerous as in the army, as in only one of the army Centers recently visited by me, there were more than twice the number of patients on that plastic service alone, than there were in all of the naval Plastic Centers combined. It is to be noted, that there is no special consultant in plastic surgery in the office of the Surgeon General of the Navy.

Now the war is over, what will be done with those men in Plastic Centers on whom plastic reconstruction has not been completed, and also with those who will require operative treatment over a period of years? The following are some of the questions asked about the subject: Will some of the present Plastic Centers be closed, and the patients concentrated in permanent military Centers? Will the treatment be continued as at present by trained plastic surgeons, from civil life, who are still in the army, or will the treatment be continued by medical officers from the regular corps? Will the army retain several trained plastic surgeons in the service to take care of these patients in military hospitals? Will these patients eventually be assigned to civil hospitals under the care of recognized civil plastic surgeons? Will arrangements be made to have the long drawn out cases sent to army hospitals, not too far away from the homes of the released surgeons, who took care of them in the Plastic Centers while in the service? Will they be kept in military hospitals, and the operative work be continued by civil plastic surgeons, who have previously been in the army, employed on a contract basis? Will these patients be assigned to the Veterans Administration and will Veterans Administration surgeons take care of them? Will the Veterans Administration induce trained and competent plastic surgeons, either from those already in the army or navy, or from civil life to enter the medical section of the Administration to take care of plastic cases, if and when, they are transferred to that administration?

As a partial reply, I have been told authoritatively, that all plastic surgical cases will be kept in the army until their care has reached maximum benefit.

Also that the army has no intention of turning these patients over to the Veterans Administration until the Veterans Administration has facilities, which are comparable with those in which the wounded men are being treated.

In this connection, it may be interesting to note how plastic surgery is handled in Canada. The Navy, Army, Air-force and Department of Veterans' Affairs have joined to provide specialty surgery of all varieties. As far as plastic surgery is concerned, these joint service special treatment Centers are in Montreal, Toronto and Vancouver. The work of these units has been supervised by a Joint Service Advisory Committee to the directors of Medical Services of the Navy, Army, Air-force and the Department of Veterans Affairs. The joining of the active services with the Department of Veterans Affairs has worked out very well for specialty surgery. Now the war is over, the Department of Veterans Affairs is taking on skilled workers from the armed services, and the units will eventually no longer be combined service but completely Veterans Affairs.

There has been sharp criticism of the organization of the Army Medical Corps under Army Service Forces and of the Surgeon General's lack of authority. This matter has recently been ably editorialized by Loyal Davis and, again, by J. Earle Moore, and is a subject which all of us should be familiar with and be prepared to do something about before we forget it, and before another war comes around. Briefly, it is as follows: The Army Medical Corps is under the authority of the Chief of Army Service Forces. The Surgeon General is badly handicapped by lack of independence and by having little control of the disposition of his own corps, either in the United States or in foreign theaters. Units or individuals, once assigned, are out of his jurisdiction and under that of the Chief Surgeon of the Service Command or group where this assignment may be, still of course, under the Army Service Forces. The function of the Surgeon General's office is principally to obtain adequate personnel, to procure and distribute equipment, to supply hospitals, and to make recommendations. The Surgeon General is not a member of the General Staff and has no direct contact with it. It is interesting to know also that frequently before purely medical regulations can be put into effect, approval must be obtained from nonmedical officers of the Army Service Forces. When attention is drawn to these conditions, the usual reply is that the Medical Corps in World War II has done splendid work under the present system, so why change? Splendid work has been done, but the Corps, largely made up of well-trained men from civil life, has done its job on account of the ability of these men, in spite of the system, and not because of it.

<div align="center">SUMMARY</div>

In World War II, American wounded service men, requiring plastic and reconstructive surgery, are getting admirable treatment by competent well-trained plastic surgeons; by splendid army nurses and by well-trained corps men.

Plastic cases are segregated in Plastic Centers. The equipment is for

the most part excellent. The prompt treatment of maxillofacial injuries and of all injuries requiring plastic reconstruction has made a great difference in length of hospitalization and in the ultimate result.

The early closure of facial wounds and the early covering of denuded surfaces by skin grafts or skin flaps has been found most advantageous. The treatment of burns is much more effective than ever before. There is a better understanding of the methods of combating shock and of the use of plasma and whole blood. Great advances have been made in building up plastic cases for operative work. The use of sulfonamides and of penicillin and other substances have prevented infections and have saved patients after infections have started.

There has been great improvement in the treatment of wounds of all kinds and in the methods of dressing wounds. There is better understanding of the handling of scar tissue. The methods of inducing anesthesia, and also of surgical technic has been improved along every line. New technics have been developed in the last few years in skin grafting and flap shifting, and, in fact, in all types of tissue transplantation, and all of these advances in knowledge are being constantly used. Another great advance is the marvelous improvement in the methods and speed of evacuating the wounded. Many more lives are saved than would have been possible in World War I, and better operative results are obtained.

Great advantage follows close coöperation between the plastic surgeon and the dental surgeon in the treatment of jaw injuries, also with the orthopedic, the neurologic, ophthalmologic and the general surgeon in their various fields. The psychologic handling of mutilated patients has been vastly improved.

The reconditioning program, with its various activities, also aids materially in helping many of the men back to a useful life. So it can be seen from this partial list that the wounded service man in World War II, who requires plastic reconstruction, is better cared for in almost every way than he was in World War I, and his chances of an excellent result are far greater.

The purpose of the Plastic Centers in the selected army and navy General Hospitals is to return the wounded man promptly to duty, or to civil life, with as normal function as possible, with the minimum of deformity and with his chin up.

I can do no better in concluding this paper than to quote in part a sentence from a letter recently sent me by Brigadier General Fred W. Rankin, Chief Surgical Consultant: "I know no finer contribution being made than your specialty is making." In other words, American Plastic Surgery is delivering the goods in World War II.

BIBLIOGRAPHY

Blair, V. P.: Relation of the Early Care to the Final Outcome of Major Face Wounds in War Surgery. Military Surgeon, 92, No. 1, 12, January, 1943.

Bunnell, S.: Surgery of the Hand. J. B. Lippincott Co., Philadelphia, 1944.

Davis, L.: Organization of the Red Army Medical Corps. Surg. Gyn. & Obst., **79,** No. 3, *329,* September, 1944.

Esser, J. F. S.: Plastic Surgery of the Face. ANNALS OF SURGERY, **65,** 297, 1917.

Filatov, V. P.: Plastie á Tige Ronde. Vestnik oftal No. 4 and 5, April and May, 1917.

Gillies, H. D.: The Tubed Pedicle in Plastic Surgery. N. Y. Med. J., **3,** 1, 1920.

Moore, J. E.: United States Army Medical Corps. Surg., Gyn. & Obst., vol. **80,** No. 3, 333, March, 1945.

McIntire, R. T.: Health Conditions in the Navy. J. A. M. A., **129,** No. 3, 215, September 15, 1945.

Rankin, F. W.: The Mission of Surgical Specialists in the U. S. Army. Surg., Gyn. & Obst., **80,** No. 4, 441, April, 1945.

Smith, Ferris: Plastic and Maxillofacial Surgery. Military Surgical Manual, W. B. Saunders Co., Philadelphia, 1942.

PERSONAL COMMUNICATIONS

Lt. Col. E. M. Bricker, M.C., A.U.S.
Col. J. B. Brown, M.C., A.U.S.
Col. E. H. Campbell, M.C., A.U.S.
Major P. Clarkson, R.A.M.C.
Lt. Col. M. E. DeBakey, M.C., A.U.S.
Wing Comdr. A. W. Farmer, R.C.A.F.
Col. R. H. Ivy, M.C., A.U.S.
Capt. H. L. D. Kirkham, M.C., U.S.N.R.
Vice Admiral R. T. McIntire, M.C., U.S.N.
Brig. Gen. F. W. Rankin, M.C., A.U.S.

USE OF CANCELLOUS BONE IN THE REPAIR OF DEFECTS ABOUT THE JAWS*

COL. T. G. BLOCKER, JR., M.C.

WAKEMAN GENERAL HOSPITAL
CAMP ATTERBURY, INDIANA

AND

CAPTAIN L. R. WEISS, D. C. (By Invitation)

WHILE it is generally recognized that reconstructive surgery had its origin in antiquity, the practice of bone transplantation belongs to modern times and the use of bone grafts for remedy of defects of the mandible is a by-product of the first World War. Cole,[13] in a preliminary report in 1919, stated that in the first two years of the war only isolated attempts were made and that "occasionally active hostility was encountered." Between 1916 and 1922, however, fairly large series were reported by Lindemann[31] of Germany; the French group, headed by Délangenière;[15] Cole,[11, 12] Bubb, and Tainter;[50] the group at Sidcup, headed by Gillies[23] and including Chubb, Fry, Risdon, Waldron, Blair, and Ferris Smith; Billington and Parrott[4]; Munby, Forty, and Shefford; Gallie and Robertson;[20] and Ivy,[26] who in 1920, gave a detailed summary of late results in the treatment of gunshot fractures of the mandible in the American Expeditionary Force. In the same year, Blair[5] made the statement that "no part of facial reconstruction received greater impetus during the war than bone grafting of the lower jaw." This was felt to be due to the establishment of close coöperation between the plastic and oral surgeon, working as a maxiliofacial team, as well as to the availability of abundant material as a result of war casualties. From available figures it may be estimated that approximately 1,000 mandibular bone graft procedures were performed by workers in all countries, mostly for nonunion and for small losses of bone.

Between the two wars defects of the mandible requiring bone grafts were limited to sporadic cases, here and there, which resulted from severe traffic injuries, bullet wounds, osteomyelitis, and operative removal of neoplasms of the jaw. In 1927, for example, Ivy and Epes[27] reported a total of nine cases at Walter Reed General Hospital for the preceding five years. During this period Ivy had treated five additional cases successfully in private practice. With the advent of the "blitz" in Europe, however, incidence of mandibular fractures began to rise. In 1941, for example, McIndoe[34] reported ten bone grafts in 119 cases of fracture which occurred during a period of 15 months in 1939–40.

Statistical summaries of World War II casualties are far from complete, and few reports have been made in the literature as yet. It is obvious, however, that the incidence of massive maxillofacial avulsion wounds has increased out of all proportion to the number of casualties in a comparative study of jaw injuries in World War I. This may be due in part to the use of missiles of higher explosive action which produce greater shattering and loss of bone sub-

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4–6, 1945, Hot Springs, Virginia.

stance. The survival of large numbers of patients with extensive injuries of the lower face results from careful training of aid men at the front line in the handling of such cases to prevent obstruction of air passages; by the routine use of plasma and blood transfusions in the early stages of injury; and lastly, by the early and prompt use of chemotherapy to prevent overwhelming local infection and generalized septicemia.

Much has been written in the last 25 years on the various aspects of bone grafting, particularly the theories of osteogenesis and the advantages and disadvantages of different types of grafts based largely upon these theories. It is not my purpose here to enter into the arguments on the intrinsic nature of periosteum, the problem of "creeping substitution" of bone grafts, the exact rôle of the osteoblast and the undifferentiated connective tissue cell in bone formation, or the effect of local tissue p_H on the mineralization of preosseous tissue. For practical purposes, as pointed out by Ghormley,[21, 22] Murray,[37, 38] Arich and Austin,[17, 18] and Fry, and his coworkers,[19] we know from experimentation and from experience that healing following transplantation of bone occurs in much the same fashion as after primary fracture. Organization of a clot occurs in the graft bed, and there is invasion by organizing vascular connective tissue at a rate which is in reverse proportion to the density of the graft. After vascularization is established, bony absorption occurs to a certain extent, as evidenced by decreased density and, finally, there is redeposit of calcium and firm bony union. According to Wolff's law, there are changes in size, shape, and strength resulting from action of the attached and surrounding muscles and in response to mechanical laws of stress and strain.[30]

TYPES OF BONE GRAFTS

Sources of bone which have been employed in remedy of mandibular defects are, first, the jaw itself in the form of a sliding or pedicle graft for losses up to 3 cm. in the body or symphysis. Grafts from the tibia include cortical grafts, which are employed almost routinely for nonunion of fractures of the long bones, and thin shavings of bone about 2 mm. in thickness, the so-called osteoperiosteal graft, for relief of small defects which are unaccompanied by soft-tissue loss or distortion of contour. Grafts from the rib have been used on occasion and where the symphysis and overlying soft structures must be restored, clavicle grafts have been employed in pedicle flaps. During the past 20 years grafts from the ilium have become almost standard procedure, especially in the case of large mandibular defects and where there is marked contour deformity. All workers agree that the rapidity of "take" of a bone graft depends in a large measure on the amount of spongy or cancellous bone present, and the ilium furnishes an abundant and easily accessible source. From clinical experience it has gradually become apparent that neither periosteum nor cortical bone is necessary for the accomplishment of firm bony union. Cancellous bone, because of its soft, vascular nature, is more easily invaded by organizing connective tissue and may perhaps actually survive as living tissue.

One purpose served by cortical bone is in acting as a splint for bone frag-

FIG. 1-A

FIG. 1-B

FIG. 1-C

FIG. 1.—Technic of Cancellous Bone Graft to Mandible:

A. Exposure of fragments. Note the anterior fragment has been exposed only far enough to get good contact while the posterior fragment has been completely freed and is controlled during the operation by a wire through the angles. The cancellous graft is shown below the wound.

B. The graft is in contact with the lingual side of the posterior fragment which in this instance gave good facial contour.

C. Wound closed with two layers of continuous No. 38 steel wire. Note the subcuticular wire is extending from the skin and is to be tied over a gauze dressing before the pressure dressing is applied.

ments in the extremities. In the jaw, however, immobilization is accomplished almost entirely by the use of mechanical appliances. For this reason it has been possible to employ grafts of pure cancellous bone from the ilium, and this procedure has been used routinely in the series to be presented. After careful

FIG. 2-A

FIG. 2-B
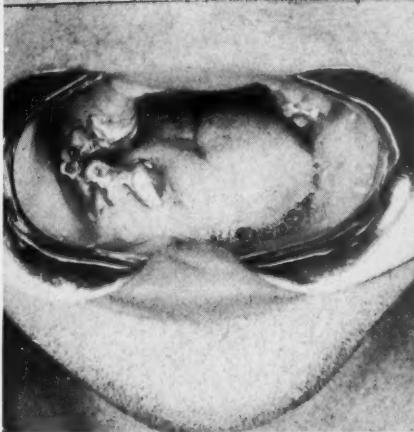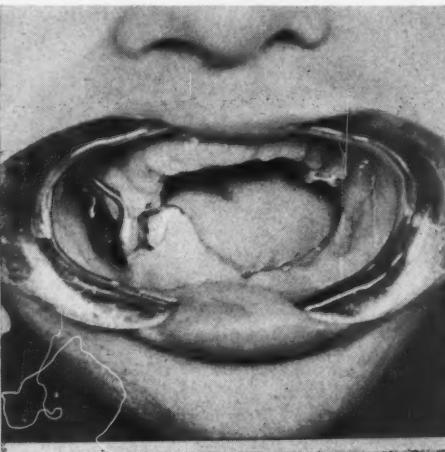
FIG. 2-C
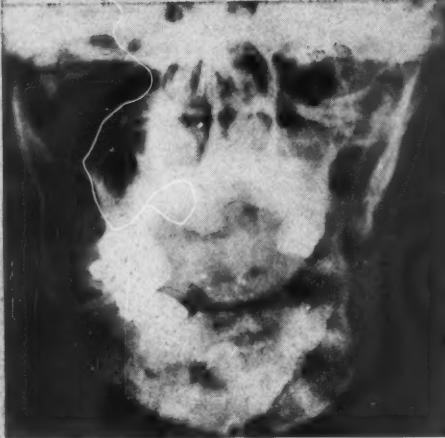
FIG. 2-D

FIG. 2.—B. N. Pfc., age 24, received a machine gun bullet wound of the face with loss of the greater portion of the left body and angle of the mandible, 10 March, 1944. He was evacuated to this country as soon as his condition permitted and all drainage had subsided and sequestra were extruded by December, 1944. On 7 February, 1945 a large one-piece cancellous graft was placed over the defect and firm union with good contour has occurred. A stent graft was placed in the left buccal sulcus 1 October, 1945, and he now has good function.

A. Roentgenogram on admission showing large loss of substance on the left and nonunion on the right.

B. Flange cap metal splint to maintain the fragment in normal position during the waiting period and at the same time allow function of the jaw.

C. Interlocking cap metal splint, used for immobilization of the jaws.

D. Roentgenogram showing large cancellous bone graft in position.

FIG. 2-F

FIG. 2-G

FIG. 2-E
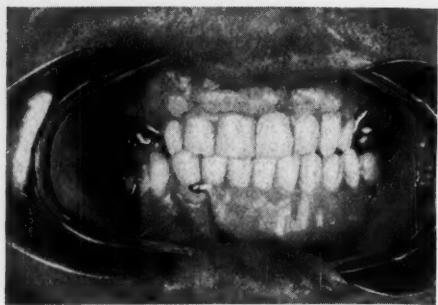
E. Contour of left face five months after bone graft.
F. Stent graft to create sulcus for denture.
G. Final denture before disposition.

removal of the cortex, the graft may easily be cut and shaped with heavy scissors or rongeurs, and successful results have been obtained in every case.

PLANS OF TREATMENT

The problems of definitive treatment of patients with severe deformities about the jaws requires close coöperation of the plastic surgeon and his dental consultant. After complete analysis of the defect from the standpoint of deformity and functional impairment, a detailed plan of treatment should be formulated and recorded with a statement of ultimate aims to be achieved and an approximate time schedule of operative procedures, stage by stage. Every effort must be made to help the patient make satisfactory adjustment, not only to his severe deformity but to the long periods of hospitalization and tedious waiting. Before surgery can be attempted he must be put in good general physical condition. Most patients with severe wounds about the jaws have suffered marked blood loss at the time of injury and show malnutrition and weight loss as a result of deficient diet. It has been our practice to restore normal weight and muscle tone by the use of high caloric diets supplemented by vitamin therapy and by the addition of large amounts of protein daily in the form of casein administered in milk shakes or malted milk drinks. Transfusions of blood and plasma are given where indicated until the patient's serum protein, blood volume, total blood count, and hemoglobin reach normal levels.

To the dental surgeon is delegated the responsibility of immobilization of bone fragments, of treating infection about the mouth of dental origin, of designing temporary splints for the maintenance of fragments in the best possible position during the waiting period and splints for absolute immobilization in conjunction with the bone grafting procedure. In many instances, removal of loose sequestra in the region of the bony loss hastens the resolution of the

FIG. 3-A
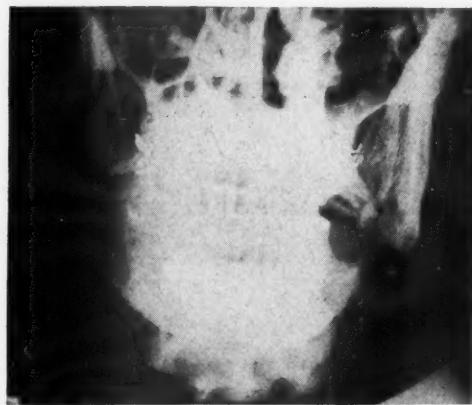
FIG. 3-B   FIG. 3-C

FIG. 3.—E. G., S/Sgt., age 26, received a shell fragment wound of the left face, 13 September, 1944, with loss of bone about the angle of the mandible. He received a bone graft 19 June, 1945, approximately five months after the extrusion of all sequestra. At operation, the posterior fragment was completely liberated and held back in its normal position by a bar attached to the interlocking cap metal splint on the teeth.

A. Preoperative roentgenograms showing bone loss.
B. Extension bar attached to splint to keep the posterior fragment in position.
C. Postoperative roentgenogram showing onlay and inlay graft of cancellous bone.

soft tissue and stops drainage. Frequently fragments of teeth are out in the tissues and act as the source of chronic drainage from an area.

Soft-tissue deformities of the lower face must be treated adequately before any bone grafting procedures may be attempted. For large avulsion deformities pedicle flaps from the thorax and abdomen must be employed to give ade-

Fig. 4-A
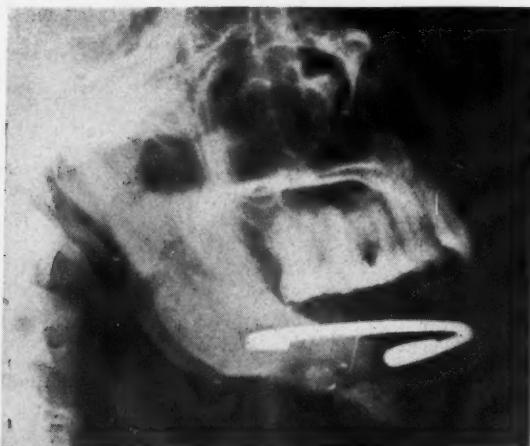
Fig. 4-B   Fig. 4-C
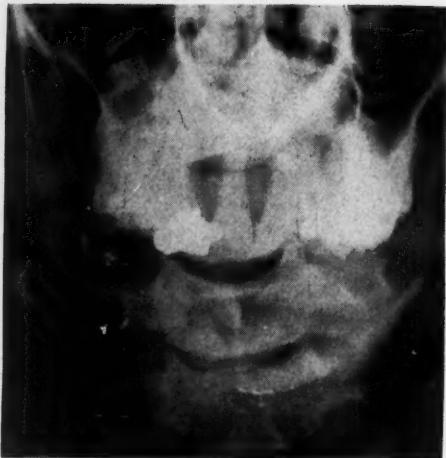
FIG. 4.—H. S., Lt. Col., age 33, received a bullet wound of the jaw 14 January, 1945, with loss of a large portion of the symphysis and the right body of the mandible. The lower jaw was edentulous on admission and a large piece of silver wire was exposed in the mouth between the fragments. One month after admission the wire was covered spontaneously and the external wound was healed. At operation, 30 May, 1945, a large salivary cyst was encountered and removed. On removal of the silver wire the oral cavity was accidentally opened. Since the ilium was already exposed it was decided to place cancellous bone along the contour of the lost mandible and maintain the fragments by a perforated tantalum plate. Drainage from the wound was constant; however, on removal of the exposed tantalum plate, 18 September, 1945, firm bony union was found to bridge the defect.

A. Preoperative roentgenogram.
B. Roentgenogram showing tantalum plate and bone graft.
C. Roentgenogram following removal of tantalum plate.

quate coverage. Less severe distortion of soft tissues may be treated by rear-rangement of existing tissues. Even small distorted scars of exit or entrance we feel should be excised early in order to give complete relaxation of covering tissue (Fig. 6).

With confidence gained since the widespread use of penicillin, there has been a tendency toward earlier bone grafting than accepted practice has formerly dictated. In several instances bone grafts have been placed over defects within six weeks following the last noticeable drainage from the area (Fig. 4); in the majority of instances we have allowed at least six months to elapse in order for soft tissues to become more supple and a large part of the deep scar to become absorbed. It has been noted that the most satisfactory convalescence and earliest return to normal function and contour have occurred in patients who were prisoners of war for long periods of time following massive injury of the lower jaw. Our civilian consultants[44, 54] have reported that in England it is not unusual for a graft to be performed with chips of bone within three weeks after injury. Cuthbert,[14] for example, in 1944, reported the use of cancellous chip grafts in five cases as soon as the soft tissues healed after débridement and removal of fragments of loose bone.

METHODS OF FIXATION

The chief problem in individual bone graft procedures of the mandible concerns not the graft so much as the method of fixation and immobilization. This varies with the size of the bony defect, position and state of dentition of the upper and lower jaw and the fragments themselves. During the waiting period the fragments should be maintained in as normal a position as possible since, except in angle defects or edentulous fragments, it is almost impossible to change the position of the fragments at operation for fear of an opening into the oral cavity.

In symphysis or body defects with teeth on both fragments a cap metal splint with rigid crossbar is very satisfactory. At the time of the bone graft two interlocking cap metal splints will hold the jaws in absolute immobilization during the healing period (Fig. 6).

Where there is an edentulous fragment on one side of the fragment containing teeth is kept in normal occlusion by a flange splint, as shown in Figure 2(b). The other fragment not containing teeth is completely liberated at operation and replaced as nearly as possible to its normal position. After a long waiting period in these particular cases it is, as a rule, easy to expose and liberate all surfaces without fear of opening into the oral cavity. At operation, the edentulous fragment is maintained by a wire through the angle tip or ramus protruding through the skin and attached to a bar coming around the face from the intra-oral splint (Fig. 3).

In edentulous upper or lower jaws some modification of the Gunning splint is used during the waiting period and also in the healing period after bone graft. At operation in these cases we believe that some internal fixation is necessary and have used a piece of perforated tantalum shaped over an impression of a normal cadaver mandible (Fig. 4).

OPERATIVE TECHNIC

The most satisfactory anesthesia for bone grafting procedures we feel is a high intra-oral mandibular block supplemented by 2 per cent novocaine for infiltration. Spinal anesthesia is employed, in addition, for removal of the iliac graft. Drapes are sutured in place to prevent slipping and accidental contamination.

In making the incision, care must be taken to prevent injury to the mandibular branch of the facial nerve. As a rule, it can be avoided by dissection downward external to the plastysma about 2 cm. below the inferior border of the mandible before approach is made to the bone fragments. At least 2 cm. of each fragment is exposed when each contain teeth and no attempt is made to shift the fragments. In the case of a ramus, angle or posterior edentulous fragment exposure can be made by stripping the periosteum for long distances without fear of entering the oral cavity.

The edentulous fragment must be detached thoroughly to get it replaced in normal position. The eburnated ends of the fragment are cut off by a sharp rongeur and the outer cortex of the mandible is removed by dental bur until an area of bleeding bone sufficient for good contact is obtained.

In the meantime the iliac crest has been exposed subperiosteally by another surgical team. A large block of ilium is obtained with a sharp osteotome and placed on a wooden block for removal of all cortical bone, which is then discarded. The donor area is closed carefully in layers with interrupted silk, and a pressure dressing is applied.

Shaping of the cancellous graft is easily accomplished with sharp-cutting rongeur. All cancellous fragments are saved and are later packed into any open spaces in the graft bed or perhaps placed along the outerborder of the mandible to improve the general contour. The graft is shaped to act both as an inlay and onlay graft and is immobilized by a single strand of No. 32 stainless steel wire. At least 2 cm. should be in contact with the bleeding bone on each fragment. Although there may be marked protuberance externally at first, the transplant undergoes rapid absorption, and the contour of the mandible is quickly established after function begins.

Complete hemostasis is obtained by ligation of all bleeding points with No. 0000 silk. Closure is made in layers, and firm pressure dressing is applied. It cannot be emphasized too much that the wound must be closed without tension, and it may be necessary for this purpose to undermine the skin for a considerable distance to obtain proper relaxation. In over half of our cases closure was made with interrupted fine silk; but after we became convinced that drainage in two cases was the result of buried silk sutures, we began to employ a single removable stainless No. 38 wire for the deeper layers and continuous running stitch of the same material for the skin.

POSTOPERATIVE CARE

Following operation patients are kept in a semisitting position, and careful attention is given to maintenance of an adequate air-way. In one instance it
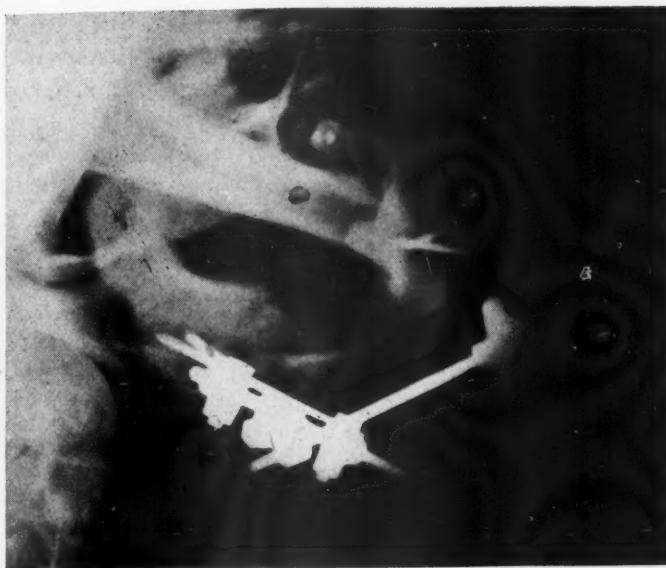
Fig. 5-A
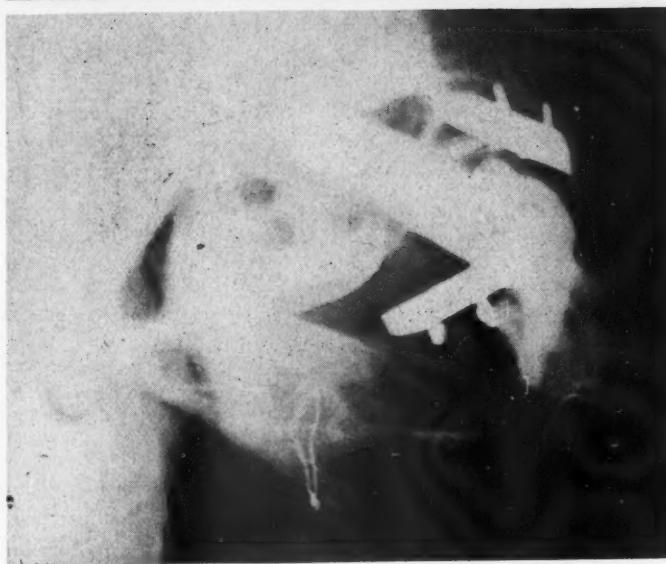
Fig. 5-B

FIG. 5.—E. V. W., Pfc., age 30, received a rifle bullet wound of the face 14 September, 1944, with considerable loss of substance of the right body of the mandible. He had an edentulous upper jaw and was admitted for definitive treatment with an external pin fixation splint on the fragments. On 11 July, 1945, approximately three months after cessation of drainage, a large cancellous bone graft was used to bridge the defect using a modified Gunning splint for fixation. Excellent union occurred.

A. Roentgenogram on admission.
B. Roentgenogram after union.

was necessary to open the intra-oral splint for 24 hours to relieve obstruction. Liquid diet is given, and oral hygiene is maintained by frequent mouth wash, and careful daily inspection by the dental consultant. It has been our routine procedure to give the patient penicillin for five days, 20,000 units in one quarter per cent novocaine solution every three hours. Pressure dressings to both the donor area and the face are maintained for a period of ten days and, as a general rule, by 14 days patients have become ambulatory. Except for mainte-

Fig. 6-A   Fig. 6-B
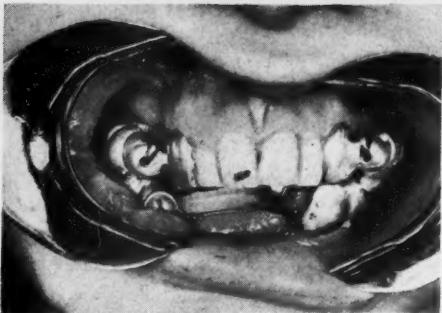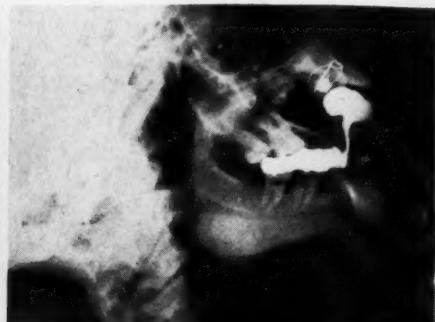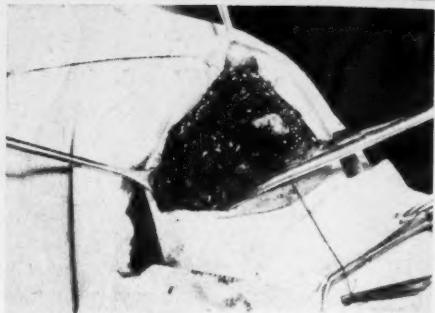
Fig. 6-C   Fig. 6-D

Fig. 6.—O. R. I., Pfc., age 21, received a shell fragment wound 29 June, 1944, with loss of considerable soft tissue of the chin and bony loss of symphysis and anterior half of right body of the mandible. The soft tissues were readjusted for better coverage 26 October, 1944, shortly after all drainage ceased and a cancellous bone graft was used to bridge the defect 20 March, 1945. The labio-alveolar sulcus was created by a stent graft 20 October, 1945, in order that a functioning denture could be used.

        A. Contracted cicatrices on admission.
        B. Roentgenogram showing bone loss.
        C. Interlocking cap metal splint for immobilization.
        D. Bone fragments exposed at operation.

nance of oral hygiene nothing further is indicated until seven to eight weeks have elapsed, at which time the cap metal splints are released and the state of clinical union inspected. If not absolutely rigid the splints are left on for another two to four weeks before removal. As soon as successful "take" is assured, patients are allowed 90-day furloughs. By the end of this period of time firm bony union has been obtained, and there is good contour of the jaw even in cases where considerable bulging was present following operation.

Dentures are fitted before furlough if possible. Otherwise when the patient returns, buccal and labio-alveolar sulci are reconstructed by stent grafts. Minor "touching-up" procedures are performed, such as alleviation of contour depressions by cartilage or derma-fat grafts. It has been interesting to note in some of these operations the condition of the bone graft which is necessarily

FIG. 6-E

FIG. 6-F
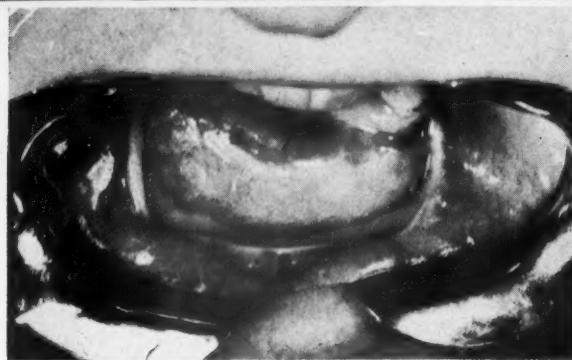
FIG. 6-G

E. Roentgenogram showing cancellous bone graft bridging the defect.
F. Appearance following bone graft.
G. Reconstructed labio-alveolar sulcus.

exposed. It is seen to be smooth and white with a well-formed periosteum; on stripping, many small reddish dots are seen as evidence of nutrient vessels.

REPORTS ON CASES

During the past 16 months 457 patients have been admitted to the Plastic Surgery Section of our Center for definitive surgery of the upper and lower jaws, 339 with defects of the mandible. One hundred sixty-seven (167) were in a state of early union in good position on arrival and required prac-

tically no treatment except maintenance of oral hygiene, restoration of function by proper dentures and readjustment of soft tissue defect. One hundred and twenty-three (123), though ununited on admission were corrected by local measures alone. Of the latter, 24 had minimal bone loss but developed union with no severe functional loss or contour deformity. Five had loss of small
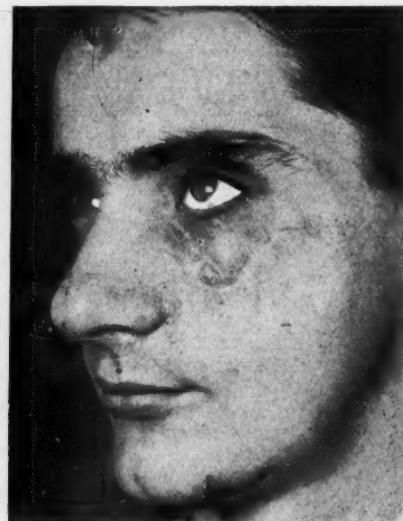

FIG. 7-A   FIG. 7-B

FIG. 7.—J. P. P., Pvt., age 19, received a shell fragment wound of the face 24 June, 1944, with fracture of left mandible and maxilla. A cartilage graft was used 24 October, 1944, which was removed because of chronic drainage. On 7 June, 1945, a large cancellous bone graft was placed over the remaining portion of the maxilla, with good contour resulting.

A. On admission.
B. Present contour.

amounts of bone in the angle region and obtained union following shifting of the ramus forward to compensate for the defect. Fifty-three (53) showed defects greater than 2 cm. and of these eight had extensive damage from avulsion of the soft structures in addition to bone, requiring replacement of the loss by pedicle flaps prior to bone grafting procedures.

At present, seven are waiting operation pending subsidence of infection and tissue reaction or in the process of repair of massive avulsion deformities. In three instances there has been considerable loss in the region of the ramus but all teeth are in occlusion and there is very little functional impairment so no bone graft is contemplated.

Forty-three (43) cancellous bone grafts from the ilium have been performed successfully to bridge defects of the mandible from 3 to 12 cm. in length. There has been drainage from the wound in eight instances; in two cases, attributable to buried silk; in two, the result of inadequate coverage; and in four, due to accidental opening into the oral cavity. Before the advent

of chemotherapy it was recommended in all instances that bone graft be aban-
doned if the oral cavity should be entered. In one of our cases operation was
postponed when this accident occurred because of the presence of a consid-
erable amount of scar tissue. In the other cases no attempt at suturing of the
opening was made since it could not be accomplished with sufficient relaxation
of the tissues to prevent tension. Operation was allowed to proceed, and the
area was drained for 48 hours. On two occasions the cancellous graft has been
fractured because of too vigorous use of the osteotome in removal of the

FIG. 8-A   FIG. 8-B

FIG. 8.—C. C., Pfc., age 19, received a shell fragment wound of the face 15 July,
1944, with avulsion of soft tissue and loss of the major portion of the left maxilla. The
soft-tissue loss was replaced by pedicle skin and, on 10 August, 1945, the contour was
restored by cancellous bone. It is believed that the majority of the pedicle skin can be
removed by rotation of the neck skin over the area and the remainder improved by color
implantation.

A. On admission.
B. Present appearance.

cortex. In each instance this has been spliced by placing a small cancellous chip
on each side of the fracture and passing a single strand of No. 38 stainless
steel wire through the fragments and chips. In each instance good union
occurred without mishap.

Other complications of operation which should be reported are mild atelec-
tasis in two instances and drainage of donor areas in two instances, one from
buried silk and one from a small piece of rubber tissue.

In the case of the maxilla, 128 patients have been admitted for definitive
treatment. Of these seven have had avulsion of considerable amounts of soft
tissue in the malar region, upper lip, orbit, or nose. The majority have been
treated by the use of cartilage grafts or by fitting intra-oral prosthetic appli-
ances into artificial skin-lined cavities in the mouth produced by stent-grafting
to restore proper contour. In nine cases, however, cancellous bone grafts have
been employed. In one of these there was accidental entrance into the orbit,
and an attempt was made to close over the opening. Although no drainage into

the orbit occurred, there was persistent drainage from the skin incision for three months.

CONCLUSIONS

It must be emphasized that the treatment of bony defects of the jaw must be planned on a long-time basis of preparation for grafting by elimination of infection, removal of sequestra and broken fragments of teeth, and by remedy of soft-tissue defects before bone surgery can be attempted. Patience and time are the most valuable adjuncts to reconstructive surgery.

With the use of cancellous bone grafts from the ilium we have obtained successful "take" in 52 cases, 43 to mandible and nine to the maxilla, and we feel this type of graft is superior to other kinds of bone in repair of large and small defects of the mandible. The selection of a graft or the modification of technic is perhaps, in the final analysis, largely a matter of individual choice, and other workers may be able to show equal success with other procedures. However, we are all working to restore normal jaw function, to improve the patient's appearance as much as possible, and to achieve these results with as much dispatch as is compatible with safety.

BIBLIOGRAPHY

[1] Abbott, LeRoy C.: The Use of Iliac Bone in the Treatment of Ununited Fractures. Am. Acad of Orth., Surgeons Lectures, 13, 1944.

[2] Albee, Fred H.: Evolution of Bone Graft Surgery, Am. J. of Surg., 63, 421, 1944.

[3] Billington, William: Bone Grafting the Mandible. Proc. Roy. Soc. Med., 23, 7, 1930.

[4] Billington, William, and Round, H.: Bone Grafting of the Mandible: Report of Seven Cases. Brit. J. of Surg., 13, 497, 1926.

[5] Blair, Vilary P.: Some Observations on Our War Experiences with Face and Jaw Injuries. Mil. Surg., 47, 379, 1920.

[6] Blair, Vilary P.: Surgical Disease of the Mouth and Jaws, C. V. Mosby, 1914.

[7] Blair, V. P., Ivy, R. H., and Brown, J. B.: Essentials of Oral Surgery. C. V. Mosby Company, 1936.

[8] Boyd, Harold: The Bridging of Bone Defects. Am. Acad. of Orthopedic Surgery: Lectures, P. 522-531, 1944.

[9] Chubb, Gilbert: A Further Series of Forty Cases of Bone-Grafted Mandibles, Lancet, 1, 640, 1921.

[10] Chubb, Gilbert: Bone Grafting of the Fractured Mandible, Lancet, 2, 9, 1920.

[11] Cole, Percival P.: Nonunion of War Fractures of the Mandible, Lancet, 1, 459, 1918.

[12] Cole, Percival P.: United Fractures of the Mandible: Their Incidence, Causation, and Treatment. Brit. J. of Surg., 6, 67, 1918.

[13] Cole, Percival, and Bubb, Charles H.: Bone Grafting in Ununited Fractures of the Mandible. Brit. Med. J., 1, 67, 1919.

[14] Cuthbert, J. B.: Comminuted Fractures of the Mandible, Lancet, 246, 748, 1944.

[15] Delangeniere, Henri, and Lewin, Philip: A General Method of Repairing Loss of Bony Substance and of Reconstructing Bones by Osteoperiosteal Grafts from the Tibia. Surg., Gynec., and Obst., 30, 441, 1920.

[16] Dickson, Frank: Influence of Infection Past or Present in Selection of Cases. Am. Ac. Orth., Surgeons Lectures, 1944.

[17] Erich, John B., and Austin, Louie T.: Traumatic Injuries of Facial Bones: An Atlas of Treatment. W. B. Saunders, 1944.

[18] Erich, John B., and New, Gordon B.: Bone Grafts to the Mandible. Am. J. of Surg., 63, 153, 1944.

19 Fry, W. Kelsey, Shepherd, P. Rae, McLeod, Alan, and Parfitt, Gilbert J.: The Dental Treatment of Maxillofacial Injuries, J. B. Lippincott Company, 1944.

20 Gallie, W. E., and Robertson, D. E.: The Transplantation of Bone. J. A. M. A., 70, 1135, 1918.

21 Ghormley, Ralph K.: Choice of Bone Grafts in Bone and Joint Surgery. ANNALS OF SURGERY, 115, 427, 1942.

22 Ghormley, Ralph K.: Preparation of Patients for Bone Grafting in Cases of Nonunion. Am. A. of Orth., Surgeons Lectures, 1944.

23 Gillies, Harold: Plastic Surgery of the Face. Oxford Med. Pub., 1920.

24 Henderson, Melvin S.: Remedies for Nonunion and Large Bone Defects. Am. Acad. of Orthopedic Surgery: Lectures, P. 514-546, 1944.

25 Ivy, Robert H.: Early and Late Treatment of the Face and Jaws as Applied to War Injuries. S. Surgeon, 11, 366, 1942.

26 Ivy, Robert H.: Late Results in Treatment of Gunshot Fracture of the Mandible. J. A. M. A., 75, 1316, 1920.

27 Ivy, Robert H., and Epes, Beverly: Mil. Surgeon, 60, 286, 1927.

28 Ivy, Robert H., and Curtis, Lawrence: Fractures of the Jaws, Lea & Febiger, 1938.

29 Kazanjian, V. H.: Jaw Reconstruction. Am. J. of Surg., 43, 249, 1939.

30 Kushner, Alexander: Evaluation of Wolff's Law of Bone Formation. J. of Bone and Joint Surg., 22, 589, July, 1940.

31 Lindemann: Quoted by Ivy, Cole, Tainter, and others.

32 Major, Glenn: Fractures of Jaws and other Facial Bones. C. V. Mosby, 1943.

33 Manual of Standard Practice of Plastic and Maxillofacial Surgery. National Research Council, W. B. Saunders Company, 1942.

34 McIndoe, A. H.: Surgical and Dental Treatment of Fractures of the Upper and Lower Jaws in War Time, Proc. Roy, Soc. of Med., 34, 267, 1941.

35 Moorehead, Frederick B.: Bone Graft to Jaw. Surg. Clin, of N. Amer., 9, 321, 1929.

36 Mowlem, R.: Cancellous Chip Bone Graft: Report on 75 Cases. Lancet, 2, 746, December, 1944.

37 Murray, Clay Ray: The Basic Problems in Bone Grafting for Ununited Compound Fractures. J. of Bone and Joint Surg., 26, 437, 1944.

38 Murray, Clay Ray: The Principles Underlying All Bone Grafting Procedures. Am. Acad. of Orth., Lectures, 1944.

39 New, Gordon B.: Bone Graft from the Crest of the Ilium for Reconstruction of the Ascending Ramus and Two-Thirds of the Body of the Lower Jaw Bone. Surg. Clin. of N. Amer., 7, 1483, 1927.

40 New, Gordon B., and Erich, John B.: Bone Grafts to Mandible. Am. J. of Surg., 63, 153, 1944.

41 Oldfield, M. C.: Some Experiences of Reparative Surgery in Middle East; With Short Review of 1,200 Cases Treated during Last Two Years. Brit. J. Surg., 32, 237-246, October, 1944.

42 Padgett, Earl: Surgical Diseases of the Mouth and Jaws. W. B. Saunders Company, 1938.

43 Parker, Douglas B.: Synopsis on Traumatic Injuries of the Face. C. V. Mosby, 1942.

44 Parker, Douglas B.: Personal communication.

45 Premister, D. B.: Bone Transplantation for Repair of Defects of the Mandible. Surg. Clinics of Chicago, 2, 241, 1918.

47 Powers, Charles: Phases of War Surgery: Bone Transplants from the Tibia to the Lower Jaw for Loss of Substance. ANNALS OF SURGERY, 70, 476, 1919.

48 Risdon, Fulton: Treatment of Nonunion of Fractures of the Mandible by Free Autogenous Bone Grafts. J. A. M. A., 79, 297, 1922.

49 Straatsma, C. R.: Plastic and Reconstructive Surgery. Mil. Surgeon, 96, 255-257, March, 1945.

⁵⁰ Tainter, F. J.: Ununited Fracture of the Mandible Treated by Bone Graft. J. A. M. A., 73, 1271, 1919.

⁵¹ Thoma, Kurt H.: A Historical Review of Methods Advocated for the Treatment of Jaw Fractures: With Ten Commandments for Modern Fracture Treatment. J. Oral Surg., 30, 399, 1944.

⁵² Thoma, Kurt H.: The History and Treatment of Jaw Fractures from World War I to World War II. Int., Abst. Surg., 78, 281, 1944.

⁵³ Todd, T. Wingate: Rôle of Cancellous Tissue in Healing Bone. ANNALS OF SURGERY, 72, 452, 1920.

⁵⁴ Waldron, Carl W.: Personal communication.

⁵⁵ Waldron, Carl W., and Risdon, Fulton: Mandibular Bone Grafts. Proc. Roy. Soc. Med., 12, 11, 1919.

DISCUSSION.—CAPTAIN H. L. D. KIRKHAM, San Diego, Calif.: There is little that anyone can add to these three excellent papers. The hand problem has been terrific in both branches of the service. In some contractures, particularly in the web of the thumb, it is difficult in using a straight abdominal or chest flap to maintain the correct position of the hand. This can be accomplished very effectively by taking the flap from the opposite upper arm, which is grasped in the correct position by the affected hand and is thus in normal position. I obtained this from Colonel Barrett Brown at Valley Forge Hospital.

There is no question that the surgeon who has used cancellous bone and cortical bone would prefer cancellous. The comparison is about the same as fresh cartilage and preserved cartilage. At the Naval Hospital, San Diego, we used preserved cartilage entirely and had absolutely no trouble. The chief reason for this was that many patients complain more of the chest and ribs than of the wound itself, whereas if you go to the icebox and get preserved cartilage and slip it in there are no complaints.

There must be complete and full coöperation between the surgical and dental departments, and it is my feeling that the dental department should bear the same relationship to plastic repair as the bracemaker does to the orthopedist.

I would like to mention that we did have a couple of plastic cases in the Navy, too, although Doctor Davis did not mention the Navy.

COLONEL EDWARD D. CHURCHILL, Boston, Mass.: I must add a few words to Doctor Davis' scholarly presentation in regard to plastic surgery in World War II. When a missile strikes there are three factors that determine the size and shape of the resulting defect: First, the damage produced by the missile itself. Tangential hits and hits on the face may cause great mutilation, but these, fortunately, are unusual. Second, the complication of infection; particularly in the maxillofacial region, infection is one of the greatest factors in producing mutilation. Infection, however, can be controlled to a great extent, and I shall not attempt to discuss it, as you are all familiar with the great advance in this War in this respect. The third factor that may determine the size and shape of the defect is the surgeon. The surgeon can very easily increase the mutilation or defect by doing the wrong thing or not doing the right thing.

Doctor Davis used the term "general plastic surgeon"; I should like you to think for a moment about a "plastic general surgeon." There are not enough general plastic surgeons to treat all wounds nor even a large fraction of the civilian cases of malignant disease, which is a comparable problem. General surgeons must be familiar with plastic technics. If a lower extremity, for example, is struck tangentially, so that the resulting wound lies transverse to the axis of the extremity, it presents a neat little problem in general plastic surgery that must be treated by a plastic general surgeon. If an incision is made this way (indicating a crucial vertical incision), the defect is increased, perhaps to the extent that the soldier will never fight again. An incision made that way will create a stellate defect, and on the fourth day when the surgeon at the Base attempts to close the wound he is in trouble. If the initial incision had been made in this way (indicating), the soldier might well have returned to duty after six weeks.

The development and departure of the specialty of general plastic surgery has left a residual and mutilating defect in general surgery. Many general surgeons and specialists

in other fields of surgery limped into war with little knowledge of the technics and principles of plastic surgery. We knew too little about the skin as a living organ—about the tension it would withstand—about the gentle handling it requires. The simple principles of the Z-plastic, of the advancement or rotation of flaps, of the avoidance of "dog ears," etc., appear to be no longer matters of general surgical technics. The vicious bites of the rat-toothed tissue forceps added to the damage produced by the enemy.

So I propose the term plastic general surgeon in an attempt to compensate for the departure of the general plastic surgeon from our midst. We must save ourselves from the need of a consulting specialist when it is desired to do a "transcutaneous" operation.

DR. OSCAR L. MILLER, Charlotte, N. C.: Anything I say will not add to the scientific aspect of these papers, but I do want to make a few general remarks appertaining thereto. It was my privilege to make a few trips to certain army hospitals during the war. I wish to mention some of the things I saw. I saw the work of these young officers, Captain Shaw and Captain Payne, in the wards at Newton D. Baker General Hospital. You saw some of the results this morning. I want to express appreciation of the policy of the Surgeon General for segregation of plastic surgery, hand surgery, amputees and many types of surgery so they could be given the most expert care. It was then possible to take specialists from all branches of surgery who could in turn make experts of such young officers as these. Of the work of Doctors Davis and Blair—plastic surgeons—you know, and Doctor Brown was in the Army. All made their contribution, directly or indirectly, in the field of plastic surgery. There are still thousands of various types of plastic cases in the Army and hands are most difficult to reconstruct. You can appreciate why it is necessary for the Surgeon General to freeze some plastic surgeons as well as other specialists.

I may never have another such opportunity, and I want to take advantage of this one to pay particular respect to the conduct of the Surgeon General's office during this war. It may have had some shortcomings, but it will go down in history, in the minds of the medical profession and in the hearts of the people of this country, as a monumental success.

COLONEL DAVID H. POER, Martinsburg, W. Va.: I merely want to restate some points made by Captain Payne and Captain Shaw, concerning the intrinsic factors in reconstruction of the hand. I was afraid it might have been lost among their nice pictures.

With regard to reconstruction of the hand as a whole, it has been stated that this is the place where several specialists meet; the neurosurgeon, plastic surgeon, and orthopedic surgeon. The person who handles it must be trained in all three of these specialties; that includes the bones, which may require grafting or realinement, the tendons which may need lengthening or suture, or in many instances transfer to prevent loss of vital function; the joints which require plastic procedures, and the suture of small nerves and replacement of skin surface with adequate fat padding. I think some of the most remarkable results have been in those cases in which the tendon from one side of the hand is brought to the other, to restore some degree of function; and the suture of the small digital nerves. Those who attempt to do all these things must realize what it entails.

DR. EDWARD M. HANRAHAN, Baltimore, Maryland: I am sorry time did not permit Doctor Davis to finish his paper. It seemed to me to be a preview of what historians of the future will have to say about the development of plastic surgery during the first and second World Wars. Maxillofacial surgery developed markedly during the first War and Doctor Payne showed how plastic surgery of the hand has developed in this War. Up to this time we have had only two men, Bunnell and Koch, who knew very much about the hand. Now we are training a number of men. In past times the ordinary run of surgeons and hospitals might have one or two serious hand cases a year, but I believe that industrial accident insurance companies and industry in general will urge that badly damaged hands be treated in special Centers and handled by these men who have done such remarkable work in this War. The damage done to extremities, with contractures, and the damage to hands, has made surgeons use every ounce of ingenuity and apply every basic principle evolved before the War in treatment of these injuries. War does

not evolve new procedures; the tube flap was developed in 1916, and this has probably been the one procedure that has given increased stimulus to general surgeons and orthopedic surgeons in their treatment of hand and other injuries where more than a mere skin covering is necessary.

Recent years have seen the development of newer metals and metallic compounds, and these have come to play an important rôle in plastic surgery. The principles of this surgery remain the same and their application has been beautifully shown in the papers of both Doctor Payne and Doctor Blocker. As one listened to these papers one could not help but wonder what is going to constitute the plastic surgery of the future. Are we going to have hand specialists, maxillofacial specialists, or general plastic surgeons? Or will the field become so important that we will have plastic general surgeons as Doctor Churchill suggests? This field is in a very active phase of development and all who are interested are well conscious of it.

DR. DARREL SHAW, Martinsburg, W. Va. (closing): I would like to take this opportunity to thank Doctor Davis for the very clear picture he presented of the situation of plastic surgery in World War II.

Captain Kirkham mentioned the problem of contractures between the first and second metacarpals. I might mention that we have realized the difficulty in getting the thumb away from the hand and still maintain position and function. It is frequently necessary, in addition to the removal of dense scar tissue, to divide the fascia of the contracted muscles. Sometimes it is indicated to sever the insertion of the abductor to the thumb and divide the attachment of the first interosseous muscle. Even then capsulotomy of the carpometacarpal joint may be required. Doing these procedures we have had little difficulty in obtaining position and maintaining function where there is not too much loss of tissue. When this is true we have done tendon transplants for apposition after the method of Dr. Bunnell. Dr. Churchill mentioned a very common problem frequently brought to the attention of plastic surgeons handling cases treated elsewhere. It is certainly a point to mention, that the eventual plastic reconstruction should be considered by those doing early surgery. Even an ill-advised incision may greatly complicate the plastic reconstruction. The plastic surgeon, I believe, has contributed definite knowledge about handling tissues and the care of wounds by virtue of the difficulties with which he is frequently faced; dealing with tissue of low vascularity, and expecting to get a very nice result from a difficult procedure. The plastic surgical concept of early wound closure by suture or grafting has been popularized by this War.

DR. JOHN STAIGE DAVIS, Baltimore, Md. (closing): I would like to tell Captain Kirkham that the only reason nothing was said about the Navy was because of lack of time. I have a paragraph in my paper on the work being done in the Navy.

urgery
1946

oably
rtho-
mere

nds,
this
apers
ould
Are
ons?
s as
l all

this
ation

and
ting
ently
the
ctor
then
ures
here
for
mon
ated
tion
may
con-
rtue
rity,
gical
Var.

otain
k of

MUSCLE-FLAP TRANSPLANT FOR THE RELIEF OF PAINFUL MONARTICULAR ARTHRITIS (ASEPTIC NECROSIS) OF THE HIP*

CHARLES S. VENABLE, M.D., AND WALTER G. STUCK, M.D.

SAN ANTONIO, TEXAS

DEGENERATIVE MONARTICULAR ARTHRITIS of the hip joint is one of the most painful chronic conditions of late middle age, and the resultant disability "sadly embitters but does not shorten the duration of life."[11] Nubian workmen in 3500 B. C. were found to be afflicted with this condition and probably all subsequent generations of humans have suffered from the malady.[21] In the 19th century, Adams, of Dublin, suggested the name "morbus coxea senilis" which is still very apt.[1] Despite its antiquity and ubiquity, treatment of this condition has been unsatisfactory because no single method has ensured relief of pain.

Etiology.—Destructive arthritis of the hip joint in adults is often secondary to injuries or pathologic changes which in some way disturb the normal circulation to the head of the femur. Damaged bone is incapable of establishing collateral circulatory pathways anywhere in the body, but especially in the head and neck of the femur, only a minimal number of blood vessels are normally present.[9, 19, 34, 35, 36] Old contusions or fractures of the hip, traumatic dislocations, inadequately treated Perthes' disease or slipped femoral epiphyses are frequently followed by erosions in the head of the femur, progressive limitation of motion, and increasing pain which are manifestations of inadequate blood supply to that region. Another common cause is the "wear and tear of increasing age and repeated trauma."[4] Significantly, this is a specific malady which usually affects only one hip and is, hence, described as monarticular hypertrophic arthritis. It is not closely related to the usual forms of arthritis and the typical manifestations of the condition are well-known.

Pathology.—The pathologic changes seen in this condition are the formation of cystic areas in the spongy bone of the head beneath the articular cartilage, with accompanying cartilaginous degeneration of ischemic origin. In the later stages of the disease there is marked deformity of the femoral head and extensive bony overgrowths about the edge of the articular cartilage of the head. While most of the destruction takes place at the point of maximum weight-bearing, other portions of the head may become sclerotic and more dense than normal, with varying combinations of destruction and bony overgrowth.[20, 33, 43]

All of these pathologic changes in the head of the femur and the adjacent articular cartilage are similar to those seen in the conditions known as "aseptic" or "quiet" necrosis. Impairment of circulation through injury to capsular vessels, or thrombosis, or infarction, or occlusive changes due to arteriosclerosis is

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4–6, 1945, Hot Springs, Virginia.

the mechanical cause of destructive effects upon the bone and cartilage of the femoral head.

Symptoms.—Most cases of monarticular hypertrophic arthritis of the hip develop in the fourth and fifth decades of life. They are usually divided evenly between the sexes, and one hip only is commonly involved. In our small group
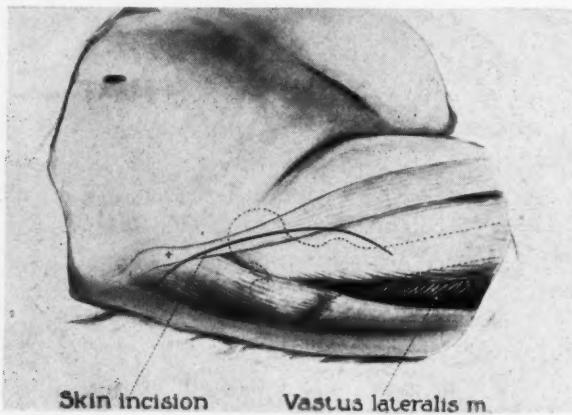

FIG. 1.—Drawing showing line of the anterior incision over the hip joint which is used to expose the neck of the femur. (From Stuck and Hinchey[42])
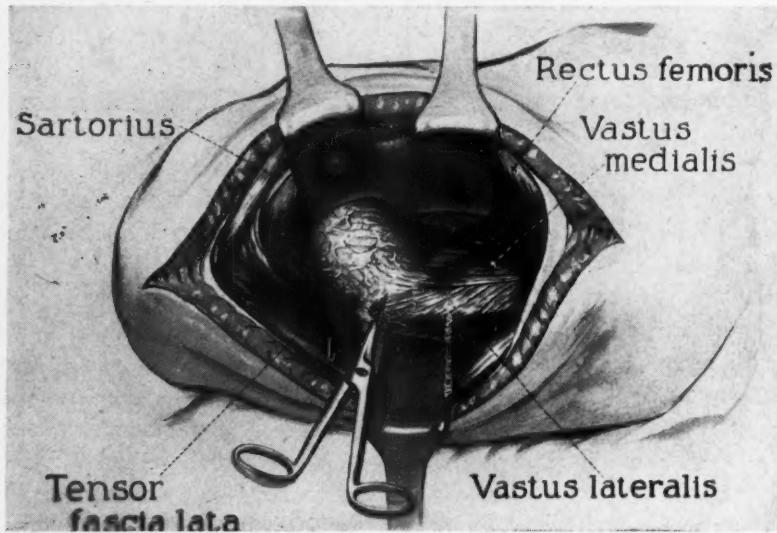

FIG. 2.—Drawing showing exposed anterior capsule of the hip joint and beginning separation of vastus lateralis muscle flap. (From Stuck and Hinchey[42])

of 27 cases, the average age was 35 years, and there were 16 males and 11 females.

The onset of symptoms is slow but progressive, with increasing stiffness and early loss of rotation and abduction. "Catching" sensations may develop

and soon constant pain becomes the most predominating symptom. The pain and associated spasm result in flexion-adduction contractures which produce a disabling limp, or creaking and grating may be noticed when the hip is moved ; but it is the constant pain which causes these patients to seek medical advice.


Vastus lateralis
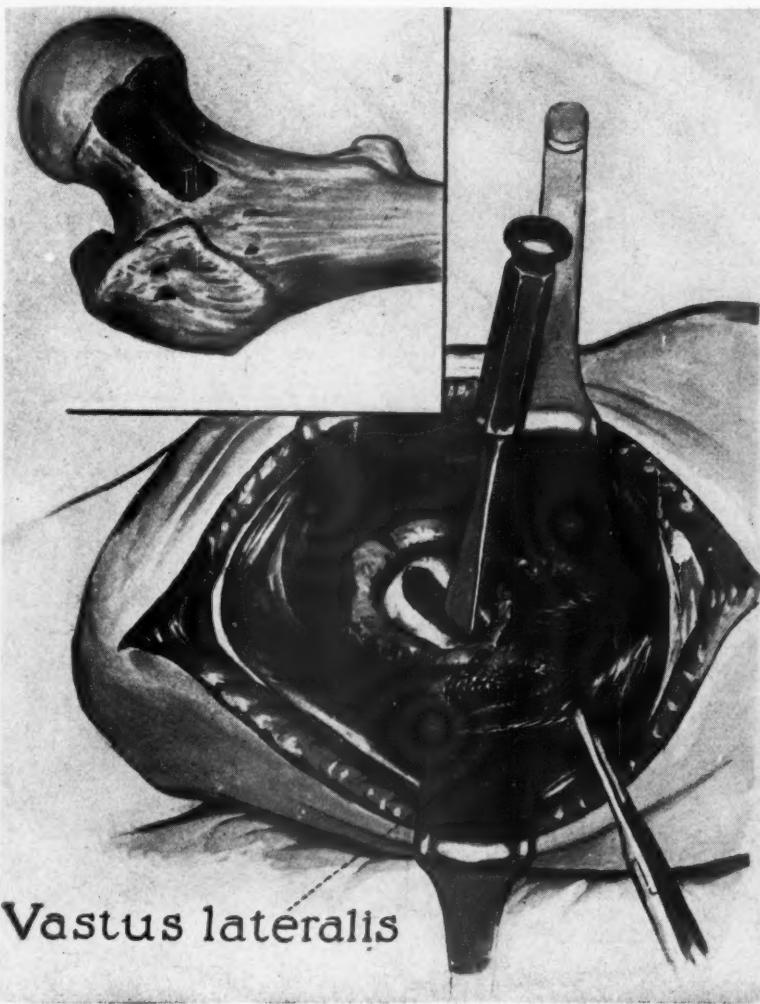
FIG. 3.—Drawing showing incision through the anterior capsule of the hip and formation of groove in femoral neck. Inset shows completed slot in the anterior surface of the neck of the femur. (From Stuck and Hinchey[42])

Roentgenograms of the hip reveal erosions in the weight-bearing portion of the head, cystic degeneration, narrowing of the joint space and much bony overgrowth about the base which produces the well-known deformed head. In the later stages, there is much flattening of the head and shortening of the neck with partial dislocation of the head and neck out of the acetabulum.

*Treatment.*—Proof that treatment of monarticular osteoarthritis of the hip
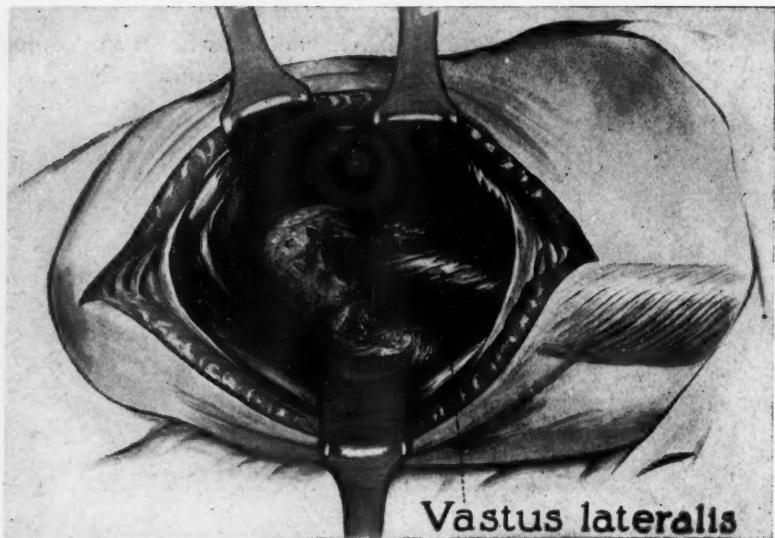
FIG. 4.—Drawing showing completed muscle-flap transplant operation, with a portion of the vastus lateralis muscle sutured into the slot on the anterior surface of the neck of the femur. (From Stuck and Hinchey[42])


FIG. 5-A   FIG. 5-B

Fig. 5.—(A) F. L. H., male, age 42, had marked limitation of motion in left hip for one year. Had had severe pain for three months. Roentgenograms show destruction of femoral head and "notching" which is occasionally observed.

FIG. 5.—(B) F. L. H. Roentgenogram of hip one month after vitallium cup arthroplasty and muscle-flap transplant operation. Four months later, patient was walking without support and completely free of pain.
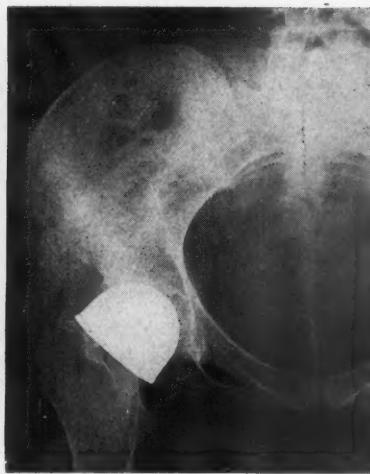
FIG. 6-A   FIG. 6-B

FIG. 6.—(A) Mrs. D. W. A., female, age 30, had fractured the right hip three years before, which was treated by well leg traction. Had pain in the right hip and knee more than a year. Roentgenogram shows marked deformity of the head of the femur, with thinning of the joint space.

FIG. 6.—(B) Mrs. D. W. A. Roentgenogram of hip four months after vitallium cup arthroplasty and muscle-flap transplant operation. Ten months after the operation, the patient was still using a cane, and had much voluntary spasm about the hip. We consider this the one case in the series which did not gain satisfactory pain relief.

FIG. 7-A   FIG. 7-B

FIG. 7.—(A) A. C., male, age 22, had had traumatic dislocation of the right hip 2.5 years previously. Had recently developed increasing pain and limp. Roentgenogram shows the typical disintegration of the femoral head in "aseptic necrosis."

FIG. 7.—(B) A. C. Roentgenogram of hip ten months after vitallium cup arthroplasty and muscle-flap transplant operation. One year after the operation, patient walks with no limp, has no pain and is on his feet constantly.
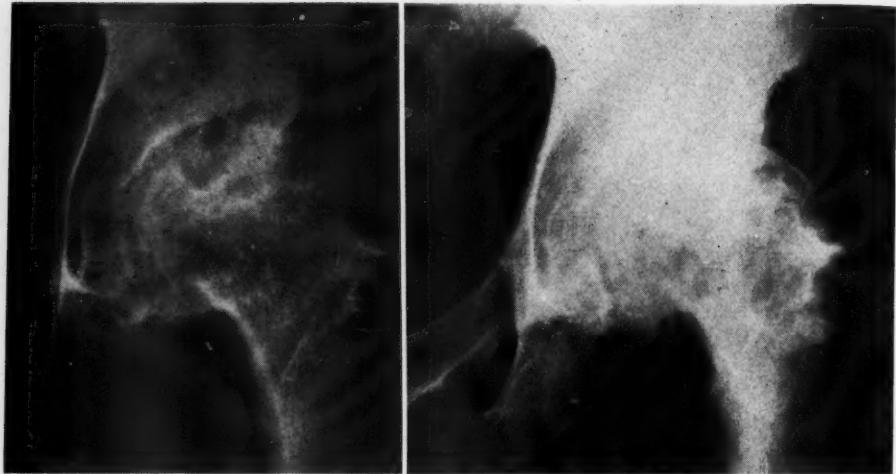
FIG. 8-A   FIG. 8-B

FIG. 8.—(A) W. G., male, age 44, for 18 months had had aching pain in the left hip, with much limitation of motion. Roentgenogram shows destructive osteo-arthritis of the hip, with cystic areas in the femoral head and much thinning of the joint.

FIG. 8.—(B) W. G. Roentgenogram of the hip seven months after muscle-flap transplant operation shows regeneration of bone in the femoral head. The patient was free of pain.
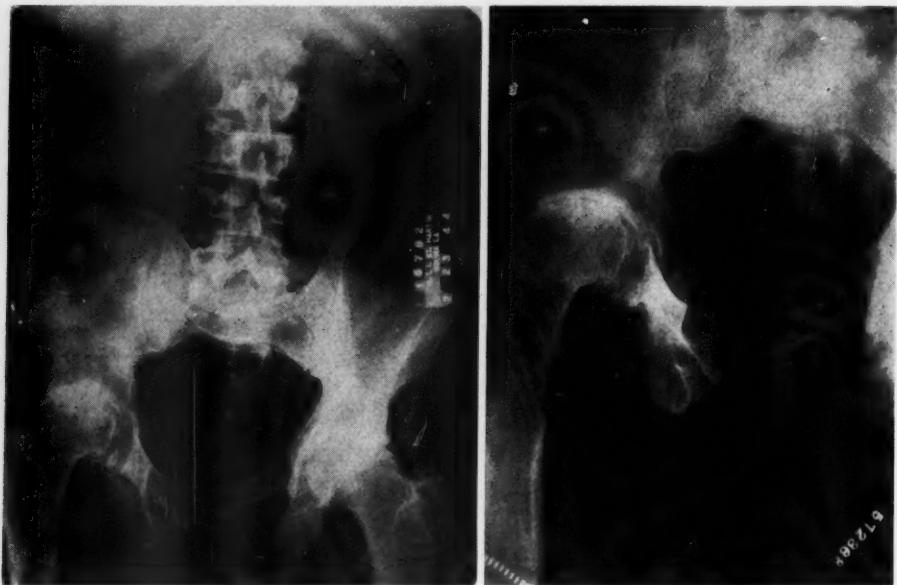
FIG. 9-A   FIG. 9-B

FIG. 9.—(A) J. W., male, age 46. Roentgenogram shows destructive osteo-arthritis of the right hip, with beginning changes in the left hip. Right hip had been painful many months.

FIG. 9.—(B) J. W. Roentgenogram of right hip seven months after muscle-flap transplant operation shows more distinct joint line and more nearly normal bone structure in the femoral head. Pain was relieved.

has not been generally successful is attested by the wide variety of measures which have been suggested and utilized at various times.

Conservative measures such as heat, rest, massage, traction, plaster casts, or crutches provide temporary relief or comparatively lasting benefit in the mild or early stages of the condition.[11] They are of no value in the fully-developed cases however.

Manipulation of the hip under an anesthetic has been advised to correct the flexion-adduction deformity and to alter the point of maximum weight-bearing. Osteotomy of the femur has been performed to achieve the same ends but relief has not been lasting after such a procedure.[16, 17, 28, 30]

FIG. 10.—A. N., male, age 41, had had old slipped femoral epiphysis of the left hip, with normal right hip. Pain on weight-bearing had increased for three years.

Muscle-flap transplant operation performed on left hip 13 months ago. The patient now works as a foreman and is on his feet all day, with no pain.

Sampson-Handley and Sir Robert Jones performed an operation they called "cheilotomy," or trimming of the marginal osteophytes about the base of the femoral head.[17] Magnuson's "joint débridement" is a similar procedure aimed at gaining more motion in the joint by reshaping of the head.[29]

Excision of the head by the Whitman reconstruction or Colonna reconstruction, gives relief of pain but leaves an unstable hip, with considerable shortening. The disability is thereby increased rather than lessened.[15, 16, 18, 46]

L'Episcopo's bone block from the ilium to the neck of the femur is planned for shifting the point of weight-bearing from the head of the femur to the top of the neck. It does not correct the adduction deformity but rather emphasizes it.[23]

Smith-Peterson's "acetabuloplasty" was conceived to increase the range of motion in the hip by the removal of impinging bony overgrowths. The supposition that pain was caused by impingement of the neck against the acetabulum has not been borne out by experience with this operation.[40]

FIG. 11-A   FIG. 11-B

FIG. 11.—(A) R. M., male, age 16, had had pain in the right hip two years. Roentgenogram shows slipped femoral epiphysis of the right hip, with normal left hip.

FIG. 11.—(B) R. M. Roentgenogram of right hip three months after muscle-flap transplant operation shows almost complete fusion of the epiphysis of the femoral head. The patient's pain was markedly lessened.

FIG. 12-A   FIG. 12-B

FIG. 12.—(A) C. B., female, age 30, had had old slipped femoral epiphysis, with stiffness of the hip for 15 years and increasing pain for one year. Roentgenogram shows usual mushrooming of the head, with sclerosis at the point of maximum weight-bearing.

FIG. 12.—(B) C. B. Roentgenogram six months after muscle-flap transplant operation shows denser femoral head and neck. The patient's pain was relieved.

Arthroplasty with autogenous fascia gave generally increased range of motion but too often did not relieve pain. There is also a tendency to loss of motion as months elapse.[18, 31, 33, 37, 46, 47]

Arthroplasty with foreign material (steel cups, pyrex glass, viscaloid, bake-lite, vitallium, *etc.*) is a simpler operation than the arthroplasty with fascia but, again, the relief of pain is often not sufficient to satisfy the patient. Motion is sometimes permanently increased it is true, but these patients are less concerned with stiffness than they are with pain.[3, 10, 13, 16, 14, 37, 41]

Fusions of the hip by bone graft, Smith-Petersen nail, multiple Smith-Petersen nail, or excision of portions of the head have for the most part given complete relief of pain. However, such operations are not easy, the patients

Fig. 13.—Mrs. C. V., female, age 62, had had fracture of the hip five years before. Fracture was nailed and healed solidly. The patient developed aseptic necrosis and deformity of the femoral head, with much accompanying pain. Removal of the Smith-Petersen nail gave no relief. Muscle-flap transplant operation relieved the pain, and the patient walks with only a slight limp.

are disabled several months and, of course, have a permanently stiff hip.[2, 5, 7, 15, 24, 45]

In other words, no uniformly satisfactory treatment has yet been developed. These patients accept stiffness and limp philosophically, so that arthroplasties to gain motion are measures to correct a secondary complaint. Pain relief is the major goal but has only been gained by excision of the femoral head or some type of arthrodesis of the joint, yet, as pointed out before, these procedures are followed by too much permanent disability.

The most direct methods for relief of pain have been the various drilling operations which have been attempted since David Brainard first suggested the
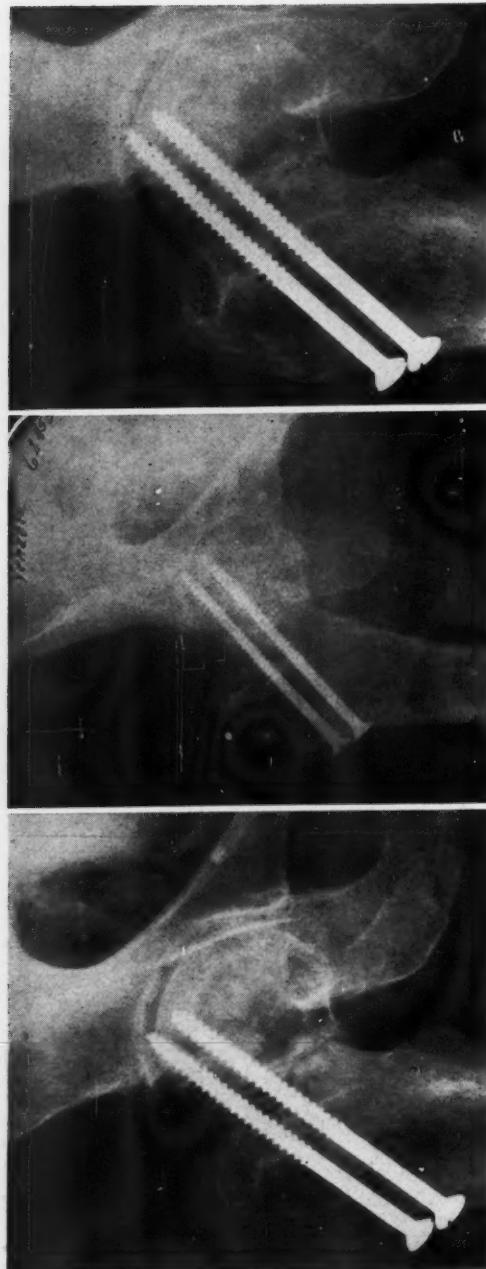
FIG. 14-A   FIG. 14-B   FIG. 14-C

FIG. 14.—(A) Mrs. J. W., female, age 65, had had a fracture of the neck of the femur which was treated elsewhere by the use of two long vitallium screws. The patient developed nonunion of fracture and pain.

FIG. 14.—(B) Mrs. J. W. Roentgenogram of the hip one month after muscle-flap transplant operation.

FIG. 14.—(C) Mrs. J. W. Roentgenogram of the hip five months after muscle-flap transplant operation showing apparent solid bony union of the fracture. The patient was able to bear her weight without pain.

idea 90 years ago.[6] It is presumed that drilling the head and neck relieves "congestion" or facilitates the passage of capillaries into the neck of the femur.[12, 25, 26, 27, 39] Many patients gain immediate relief from drilling the femoral neck, but the operation has been criticized because the relief is temporary. "Decompression" of the neck is of value, but openings in the bone usually refill with bone in a short time and the pain returns.

MUSCLE-FLAP TRANSPLANT

In 1943, Stuck and Hinchey[42] performed a series of animal experiments on the blood supply to the hip and developed a method of increasing the blood supply by a muscle-flap transplant. They followed a lead from Carl Beck's experiments, in which a pedicle-flap of pectoralis major muscle was transplanted into ischemic areas in the heart wall. In these experiments muscle was transplanted into drill holes through the trochanter or into a large defect over the trochanter, but finally the most effective method was found to be the transplantation of a muscle flap into a longitudinal slot cut on the anterior surface of the neck of the femur. In this latter operation, Stuck and Hinchey were able to demonstrate, by injected specimens and by pathologic sections,* new blood vessels growing from the muscle flap through the slot in the femoral neck and into the spongy bone of the head of the femur. Since this muscle-flap transplant operation was found to provide auxiliary circulation to the head of the femur, and since painful arthritis of the hip is presumably of ischemic origin, and since drilling operations have been unsatisfactory, Stuck and Hinchey devised a similar operation to be performed upon patients with this condition.[42]

Through a curved anterior incision over the hip, the sartorius and rectus femoris muscles are exposed and retracted medially. Blunt dissection is carried down to the capsule of the hip joint and this is incised longitudinally. A slot, about 1 x 4 centimeters, is cut in the neck of the femur from the base of the head to the trochanteric region. A flap from the medial half of the vastus lateralis muscle is dissected free and transplanted into the slot in the neck of the femur. It is anchored with several sutures through the capsule. The wound is then closed in layers.

After the operation, the patients gain rapid relief of pain from the "decompression" of the neck. However, unlike the drilling operations, this pain relief persists because the muscle flap keeps the opening in the bone from closing and in a short time an auxiliary blood supply is directed into the head.

In the first operations we performed this muscle flap at the time we did a vitallium cup arthroplasty. However, we soon discovered that the patients gained relief of pain and sufficient relaxation of muscle spasm if the muscle flap was performed without doing to vitallium cup arthroplasty. Now we have been doing the muscle-flap transplant alone and have found that the

---

* The pathologist's report stated: "Blood vessels effected a direct connection between the perimysium of the striated muscle and periosteum. There was an intimate union between the muscle implants and adjacent bone."

patients gain adequate improvement in pain and function from this simple surgical procedure. Invariably, the patients have remarked on the relief of the deep gnawing pain which plagued them even in bed. Moreover, postoperative roentgenograms have frequently demonstrated increased proliferation of bone and partial regeneration in the head.

The muscle-flap transplant operation has been performed on 27 patients with osteo-arthritis of the hip secondary to old dislocations, adolescent Perthes' disease and slipped femoral epiphyses, old malunited fractures, and the group classed as monarticular arthritis of unknown origin. Of the 27 patients operated upon, 26 have gained marked pain relief, which has lasted as long as two years since the first operations were performed.

The operation is relatively simple, long hospitalization is unnecessary, and postoperative care consists mainly of early motion and weight-bearing. The patients are satisfied afterward, even though the deformity of the head is unchanged and the limp persists, because their pain is relieved and they can resume normal activity.

SUMMARY

Painful osteo-arthritis of the hip is a relatively common chronic condition of middle age which produces much pain and disability.

The destructive arthritis of the femoral head follows old adolescent Perthes' disease, slipped femoral epiphyses, dislocations, fractures, or the normal wear and tear of life. Whatever the remote causes, the pathologic changes in the femoral head are due to alterations in the normal blood supply.

We have developed a muscle-flap transplant operation in the head and neck of the femur to overcome the symptoms of "aseptic necrosis" and painful osteo-arthritis. This operation has been performed upon 27 patients and, in all but one case, there was striking relief of pain which has persisted as long as two years afterward. The operation is relatively simple and is indicated in cases of osteo-arthritis of the hip where pain and disability are severe or progressive.

BIBLIOGRAPHY

[1] Adams, R.: Todd's Cyclopedia of Anat. and Physiol., Longman's, London, 1836.

[2] Bailey, E. T., and Burrows, H. J.: Nail Fixation of Osteo-arthritic Hip without Exposure of Joint, Lancet, 1, 980, 1939.

[3] Baker, L. D., and Waters, C. H.: Vitallium Cup Arthroplasty of the Hip. Arch. Surg., 44, 531, 1942.

[4] Bauer, W., and Bennett, G. A.: Experimental and Pathological Studies in Degenerative Type of Arthritis. Jour. B. & J. Surg., 18, 1, 1936.

[5] Blount, W. F.: Personal communication.

[6] Brainard, D.: On Treating Ununited Fractures by Drilling. Trans. A. M. A., 7, 557, 1854.

[7] Burns, B. H.: Fixation of Osteo-arthritic Hip by Nailing. Lancet, 1, 978, 1939.

[8] Campbell, W. C.: Surgery of the Ankylosed Joint. S. G. & O., 55, 747, 1932.

[9] Chandler, F. A.: Observations on Circulatory Changes in Bone. Am. Jour. Roentgen. and Rad. Therap., 44, 90, 1940.

[10] Cole, W. H.: Use of Vitallium in Surgery: With Special Reference to Cup Arthroplasty. Proc. Roy. Soc. Med., 35, 779, 1941.

11 Gaenslen, F. J.: The Diagnosis and Treatment of Chronic Lesions of the Hip Joint. Minn. Med., **4,** 630, November, 1921.

12 Graber-Duvernay, J.: Un Traitement Nouveau de L'arthrite Chronique de la Hanche: le Forage de l'epiphyse Femorale. Jour. Med. de Lyon, **13,** 531, 1932.

13 Haggart, G. E.: Degenerative Arthritis of the Hip Joint. J. A. M. A., **128,** 502, 1945.

14 Harmon, P. H.: Arthroplasty of the Hip for Osteo-arthritis Utilizing Foreign Body Cups of Plastic. S. G. & O., **76,** 347, 1943.

15 Henderson, M. S.: Rôle of Fusion Operations as Applied to the Hip Joint. B. M. J., **2,** 327, August 19, 1933.

16 Henderson, M. S., and Pollock, G. A.: Surgical Treatment of Osteo-arthritis of the Hip Joint. Jour. B. & J. Surg., **22,** 923, 1940.

17 Hey-Groves, E. W.: Surgical Treatment of Osteo-arthritis of the Hip. B. M. J., **1,** 3, 1933.

18 Jones, E.: The Orthopedic Treatment of Chronic Arthritis. Calif. and West. Med., **43,** 125, 1935.

19 Kahlstrom, S. C.: Aseptic Necrosis of Bone. S. G. & O., **68,** 631, 1939.

20 Kelikian, H.: Chronic Arthritis. S. G. & O., **76,** 469, 1943.

21 Kelly, L. C.: Osteo-arthritis of the Hip. Ohio State Med. Jour., **39,** 26, 1943.

22 Kuhn, J. G.: Chronic Monarticular Arthritis. New Eng. Med. Jour., **232,** 128, 1945.

23 L'Episcopo, J. B.: Bone Block for Painful Hips. Jour. B. & J. Surg., **20,** 901, 1938.

24 Levinthal, D. H., Logan, C. E., Kohn, K. H., and Fishbein, W. I.: Practical Management of Arthritis. Indust. Med., **13,** 377, May, 1944.

25 Mackenzie, J. F.: Suggested Surgical Treatment of Bone in Rheumatoid Arthritis. Med. Jour. Australia, **1,** 441, 1931.

26 Mackenzie, J. F.: On the Deliberate Opening of Bones as a Treatment for Rheumatoid Arthritis. Med. Jour. Australia, **2,** 690, 1932.

27 Mackenzie, J. F.: Osteo-arthritis of the Hip and Knee: Description of Surgical Treatment. B. M. J., **1,** 306, 1936.

28 McMurray, T. P.: Osteo-arthritis of the Hip Joint. J. B. & J. Surg., **21,** 1, 1939.

29 Magnuson, P. B.: Joint Débridement: Surgical Treatment of Degenerative Arthritis. S. G. & O., **73,** 1, 1941.

30 Malkin, S. A. S.: Femoral Osteotomy in Treatment of Osteo-arthritis of the Hip. B. M. J., **1,** 304, 1936.

31 Meyerding, H. W.: Surgical Treatment of Chronic Arthritis. J. A. M. A., **92,** 751, 1931.

32 Murray, C. R.: Personal communication.

33 Nicod, P.: Deforming Arthritis of the Hip. Schweiz, Med. Wchnschr., **72,** 221, 1942.

34 Pemberton, R., Goldhalft, A. D., and Wright, L. M.: The Production of Hypertrophic Arthritis by Interference with the Blood Supply. Am. J. Med. Sc., **180,** 386, 1930.

35 Phemister, D. B.: Fractures of Neck of Femur, Dislocations of the Hip, and Obscure Vascular Disturbances Producing Aseptic Necrosis of Head of Femur. S. G. & O., **59,** 414, 1934.

36 Sawyer, M. H., and Ghormley, R. K.: Pathologic Study of Hypertrophic Arthritis of the Hip. Surgery, **9,** 381, 1941.

37 Selig, S.: Surgical Treatment of Chronic Arthritis. N. Y. State Jour. of Med., **39,** 2114, 1939.

38 Simpson, W. C., and Henderson, M. S.: Painful Osteo-arthritis of the Hip: A Surgical Treatment. Proc. Staff Meeting Mayo Clin., **12,** 577, 1937.

39 Smith, Noble: Bone Drilling in the Neighborhood of Inflamed Joints and Elsewhere. B. M. J., **1,** 416, 1890.

40 Smith-Petersen, M. N.: Treatment of Malum Coxae Senilis, Old Slipped Upper Femoral Epiphysis, Intrapelvic Protrusion of the Acetabulum, and Coxa Plana by Means of Acetabuloplasty. J. B. & J. Surg., **23,** 869, 1936.

41 Smith-Petersen, M. N.: Arthroplasty of the Hip: A New Method. Jour. B. & J. Surg., **21**, 269, 1939.

42 Stuck, W. G., and Hinchey, J. J.: Experimentally Increased Blood Supply to the Head and Neck of the Femur. S. G. & O., **78**, 160, 1944.

43 Thompson, J. A.: Discussion on Osteo-arthritis. Proc. Roy. Soc. Med., **22**, 1119, 1928.

44 Watson-Jones, R.: Arthrodesis of the Osteo-arthritic Hip. J. A. M. A., **110**, 278, 1938.

45 White, W.: Smith-Petersen Nail Fixation in Hip Disease. South. Med. Jour., **36**, 333, 1943.

46 Wilson, P. D., and Osgood, R. B.: Reconstructive Surgery in Chronic Arthritis. New Eng. Jour. Med., **209**, 117, 1933.

47 Wilson, P. D.: Arthroplasty of the Hip Joint. Jour. B. & J. Surg., **42**, 474, 1942.

DISCUSSION.—DR. CHARLES S. VENABLE, San Antonio, Texas: I first want to make it very clear that this is entirely Dr. Stuck's "baby." I was a bystander, more or less innocent, while his experiments were going on, and became enthusiastic when the pathologist was able to show definite regeneration of bone in the head of the femur. So we came to the period when we put these transplants in with a hip cup, and were not able to see much difference, but the astounding thing was that without the hip cup or any other outside influence, within days there was cessation of pain. I did not mention it to him, and he did not mention it to me—it was a difficult thing to explain and still is, except that perhaps the congestion of the blood supply in the hip is relieved by decompression. I think the only explanation for the pain relief is the decompression. We anticipate the regressive change in the blood supply to the head. We think possibly after the immediate relief, the progressive and continued relief of pain—which may be seen iu follow-up in the skiagram which shows the difference in the appearance of the head of the femur—there is more space between the articular surfaces. The most interesting singular cases are not only monarthritic joints, but cases of delayed union of fractures in old people. The slides showed a woman, 68 by the score in the Bible and probably 78 by the score of the Lord. She had regression of bone cells at the fracture site. A muscle transplant was done and in 60 days you could see definite early union and at the end of 90 days she was feeding her chickens, which interests me, too.

I wanted you to know this first hand. I think you are open-minded and will be interested in seeing what happens under these changed conditions, and if Doctor Stuck can develop something to relieve these poor devils who never have been relieved for long by anything I have heard of, it will be well worth while.

DR. G. W. N. EGGERS, Galveston, Texas: I have had the opportunity of hearing Doctor Stuck speak of this before. Doctor Venable said it was excellent, Doctor Stuck said he thought it was good, and I figured probably it was fair and I would try it. Possibly I have the unusual honor of being the first to do this operation under their information, so possibly, like the virgin, I may tell of my first experience!

The approach is the anterior approach to the hip joint with which you are all familiar. The systemic reaction is not too great. I believe that when you do something someone else has proposed and endorsed, you have the reaction that you operate not only with the idea of seeing and performing the technical procedure, but also the feeling that you have to be convinced. That was the attitude with which I approached it, and my feeling is this: The vastus lateralis was sensitive in this area and was easy to influence in regression from the neck of the femur. The second point is that the muscle in this area has very few strong fascial bands by which you might anchor it. Third, I wanted to see what the natural blood response would be, so I made drill holes and worked toward the head. You can see the variation in blood response as you make the holes. The bone is quite thin here in the anterior portion of the neck. The only thing I found that helped me was that I was able to anchor the vastus lateralis much more securely to the rectus femoris, and then allow it to drop into the neck of the femur with no tension. To prevent tension I suggested the use of leg traction or a splint to prevent knee flexion. The large lateral cutaneous nerve of the thigh must not be damaged.

That was my experience with it, and I believe it has possibilities. I certainly hope it will open a greater advance than we anticipated and think it may push into oblivion

the vitallium cup or other devices used in this region for arthroplasty of the hip joint, which I do not think are satisfactory for the relief of pain.

DR. RALPH G. CAROTHERS, Cincinnati, Ohio: Those of us who have had the opportunity to pin hips over a number of years have been struck with the type of case, one of which Doctor Stuck showed. Many of us feel if we could anticipate the dead head from the beginning we might remove the head primarily or do an osteotomy. I wonder if and when we can determine which of our cases is going bad, Doctor Stuck's operation might be done as a primary procedure when the hip fracture is seen first. I do not know, but it is a thought.

DR. J. ALBERT KEY, St. Louis, Mo.: I cannot see any rhyme or reason to this operation. The disease is just as much in the acetabulum as in the head of the femur. I am not at all sure that avascularity has anything to do with the pain. I have tried all the operations he mentioned and have also added obturator neurectomy, and the one I like best is the Smith-Petersen acetabuloplasty, plus the neurectomy.

I feel very much discouraged about these hips and have come to the point where my most useful therapeutic measure is a crutch or cane. The immediate relief of pain following the operation must be due to nerve section. I have used drilling without relief of pain. I have done arthroplasties and many are unstable or painful. I am going to try this operation because I have faith in the authors and in spite of the fact that I have not the faintest idea why it should be beneficial.

DR. WILLIAM DARRACH, New York, N. Y.: Albert Key has brought this up, but it was Clay Murray who thought of swinging the muscle in at the time of operation on the neck of the femur, because we had so many cases with insufficient blood supply. We tried it on 21 cases and could not see that there was any difference in the percentage of poor and necrotic heads, and stopped doing it. I think the suggestion of stripping away of the dense fibrous mass in the capsular region is good. We found that if you take a muscle and turn it around and put it in the slot while the patient is under anesthesia, it is best to use precautions so that when he regains consciousness he will not just yank the muscle out of the slot; we have known that to happen.

DR. WALTER STUCK, San Antonio, Texas (closing): Doctor Venable says this is not his "baby." At least he was in the room when the initial conception took place!

Doctor Eggers has found, as we have, that the flap of vastus lateralis muscle must be freed for five or six inches to prevent undue tension. We have been anchoring the flap to the hip capsule with wire sutures.

Doctor Carothers' interest in performing this operation at the time of nailing of a hip fracture is related to Dr. Clay Murray's work. He tried some such procedure but used a very small hole at the fracture line and it was not successful. Moreover, it necessitated too much surgery.

Doctor Key can see no reason for the striking relief of pain after this operation. Neither can we, except that the eventual increased circulation may account for it. The point is that the patients are comfortable and content, and that is their sole concern. They are not interested in roentgenograms or pathologic findings. All they are seeking is relief from constant progressive pain.

FIXATION OF TENDONS, LIGAMENTS AND BONE BY BUNNELL'S PULL-OUT WIRE SUTURE*

J. Albert Key, M.D.

St. Louis, Mo.

FROM THE DEPARTMENT OF SURGERY, WASHINGTON UNIVERSITY SCHOOL OF MEDICINE, ST. LOUIS, MO.

Other things being equal the incidence of postoperative complications will vary directly with the amount and irritating qualities of foreign material which is left in the wound. This is true both of infection and of adhesions, and is especially true of such operations as the repair of tendons, where success depends upon free movement of the sutured structure in the surrounding tissues. It is also true of areas in which the adjacent tissues are subjected to movement or to pressure. Consequently, sutures in tendons, muscle insertions and in areas adjacent to joints should be as simple and nonirritating as possible. Complicated sutures not only implant an excess of foreign material into the wound, but increase the amount of tissue necrosis caused by the suture. In the repair of tendons fine silk has been found to be superior to catgut because it is less bulky, less irritating to the tissues and less apt to be followed by infection.[1]

Fine stainless steel wire (No. 34) was introduced by Babcock[2] as suture material in 1934, and was used by Bunnell[3] for tendon sutures about four years later. It is relatively strong and causes a minimal reaction in the tissues. Bunnell found that the wire might fragment in areas where there had been continual movement over many months, but that this apparently did no harm. Occasionally he noted signs of mechanical irritation from the wire in areas subjected to movement. Consequently, he devised a pull-out wire suture which immobilized the ends of the repaired tendon and held them in apposition until healing occurred and then the wire could be removed, leaving no foreign material in the wound or only a minute coapting suture of fine silk.

In his book on "Surgery of the Hand" Bunnell[4] describes his method of fixing tendons of the fingers to bone and mentions the use of pull-out sutures of heavier wire (No. 30) in the repair of larger tendons, such as the biceps and achillis tendons. It is evident that this method has certain advantages, but it has not come into general use and it occurred to me that experience with the method by another surgeon might be of interest. I have used the method in the repair of tendons of the hand, in fractures of the patella, in the repair of ligaments and especially in the fixation of tendons to bone in tendon transplants.

In the repair of tendons the pull-out suture owes its efficiency to the fact that only the proximal end of the severed tendon tends to retract while the

distal end remains relatively immobile if the parts are immobilized. It is applied as follows: Each end of a piece of the fine stainless steel wire (No. 34 for fingers) about a foot long is threaded on a fine needle and bent back and twisted on itself. One needle with the wire is passed directly through the proximal fragment of the tendon about one-half of an inch or more from the cut end and with the needle slanting diagonally distalward, is woven back and forth through the tendon three or four times, care being taken to prevent kinking of the wire as each stitch is pulled taut. Kinking can be prevented by having an assistant guide or if necessary untwist the wire with a pair of smooth thumb
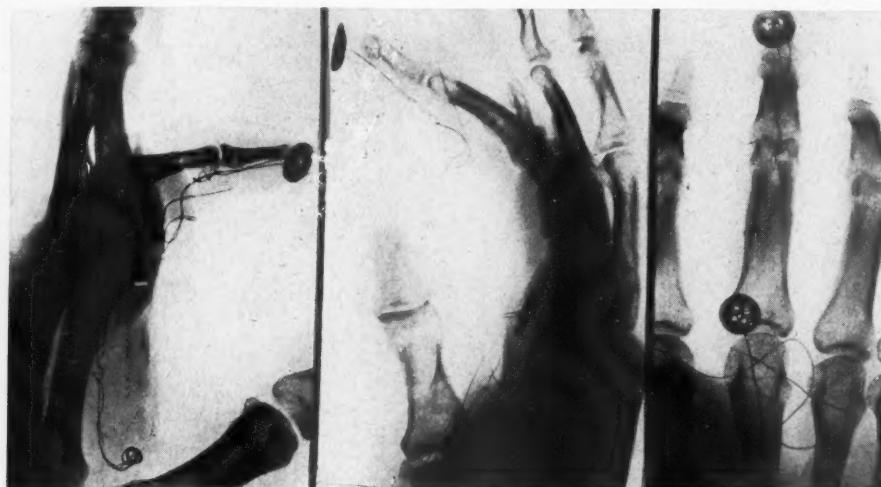

Fig. 1.—Pull-out wire fixation of tendon graft for repair of deep flexor tendon of the little finger (left) and of the middle finger (right).

forceps as the loop is pulled down against the tendon. The other end of the wire is likewise woven through the distal portion of the tendon, but before pulling the first loop taut a pull-out wire suture is placed under the loop.

This pull-out wire suture is a piece of No. 34 stainless steel wire about a foot long which is bent sharply in its middle portion. After it is placed beneath the loop its ends are caught with a light hemostat.

When the two ends of the wire which have been woven through the tendon have been pulled taut the short remaining end of the tendon is cut off and further traction on the wires causes them to sink into the substance of the tendon end. They are then passed down the center of the distal fragment of the tendon or graft for an inch or more and the fine needles are removed and both ends of the anchoring suture are threaded on a larger needle.

The proximal portion of the tendon is then pulled down into position and the larger needle is pushed through the skin distal to this point and removed from the wires which are then passed through a button and pulled taut to fix the end of the tendon in the desired position and tied over the button.

The distal portion of the tendon is then pushed down the wire against the proximal portion and fixed with a single coapting suture of fine silk. The ends of the pull-out suture are then threaded on a needle and brought out through the skin proximal to the tendon suture and left slack. The wound is closed and the part immobilized in a plaster of paris splint or encasement in a position which relaxes the sutured tendon.

Three weeks later, when union of the tendon ends is sufficiently firm, the anchoring wire is cut under the button and traction on the pull-out wire removes it from the tissues. Bunnell states that if difficulty is encountered in pulling it out the end of the pull-out wire should be fastened to a light rubber

FIG. 2.—Double pull-out wire fixation of the patella used in repairing an old rupture of the patella ligament.

band which is then fixed under tension to the skin proximal to the wound and that the wire will be out within 24 hours. In my experience this has not been necessary as all of the wires were pulled out without difficulty, nor have there been any infections in any of the wounds.

In fixing tendons to bone Bunnell scrapes the bone or lifts up a thin flap of bone, perforates the bone with a dental drill and passes the anchoring wires through the hole in the bone and out through the skin and the tendon end is then snugged down against the bone and the wires are tied over a button. Three weeks later the anchoring wire is cut under the button and removed by means of the pull-out wire.

It is difficult to state whether or not the pull-out wire suture is better for uniting tendons in the hand than the suturing with fine silk, which we have used in the past. In my hands, the wire is a little more difficult to use as it kinks very easily and this must be guarded against constantly, and the fine wire is hard to see in the wound. Likewise, the wire tends to cause splitting of a small

tendon graft, such as one from the palmaris longus, more frequently than does fine silk. On the other hand, in no instances has the wire broken as sometimes happens at a critical point when uniting tendons with fine silk.

Undoubtedly the removal of the suture after union of the tendon has progressed to a point where this can be done with safety, is the chief advantage of the method. But when fine silk is used properly this advantage is minimized and it is probable that in the hands of an expert the functional results will be about the same. In the hands of the average surgeon who does only an occasional delicate tendon repair the results should be better where the pull-out wire suture is used. This in spite of the fact that the surgeon may find the operation a little more difficult, and this is my situation.

FIG. 3.—Double pull-out wire fixation of the patella in Thompson's method of suturing the ligament or tendon to the major fragment after a fracture of this bone.

In fixing tendons to bones and especially to small bones the method appeals to me as being superior to and less technically difficult than any method which I have used in the past. In tendon transplants in the foot it is especially useful and may even be time-saving. Here a hole large enough to accommodate the tendon is drilled through the bone and the anchoring wire is threaded on a long straight needle and passed through the hole in the bone and out through the skin on the opposite side of the foot. Then the tendon is pulled down into the hole in the bone and the ends of the wire are tied over a button or bar of suitable size.

After the anchoring wire is tied over the button the part must be held in a

position in which the transplanted tendon is relaxed until the wound is closed and the part is immobilized in a suitable splint or a plaster of paris encasement. This efficient external splinting seems to me to be even more important with the pull-out suture than with buried silk sutures which remain *in situ*. In one of my cases in which the extensor tendon of the fifth toe was transplanted to the neck of the fifth metatarsal a plaster encasement was not considered necessary, the anchoring wire was found broken when it was removed four weeks
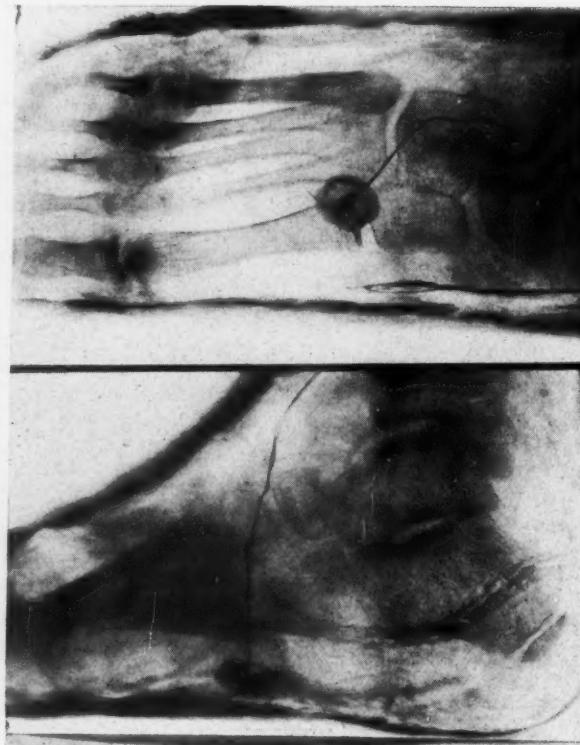

FIG. 4.—Pull-out wire fixation of the transplanted anterior tibial tendon to a tunnel in the cuboid.

later. Fortunately, the tendon had not retracted enough to lose contact with the bone.

It is this necessity for prolonged external fixation which is an objectionable feature in the use of this method for the repair of larger tendons, such as the quadriceps or achillis tendon. When the anchoring wire suture is removed nothing is left except the weak coapting silk sutures. Consequently, external fixation must be continued until the parts are quite safely healed.

Figure 3 illustrates the repair of a fracture of the patella by Thompson's method of excising the distal fragments and suturing the proximal fragment to the patella ligament. In this case the patella was held down by the two

anchoring sutures of No. 30 stainless steel wire which emerged below the tibial tubercle and were tied over wooden cross bars. The postoperative course was uneventful, but it was not considered safe to remove the encasement and the wires until five weeks after the operation. The same was true of the case illustrated in Figure 2, which was an old neglected rupture of the patella ligament which was repaired in much the same manner except that anchoring sutures were placed in the ligament as well as in the bone, thus pulling them together.

During the past three years I have operated upon two cases in which the heavy silk sutures caused trouble. One was a heel cord which had been severed
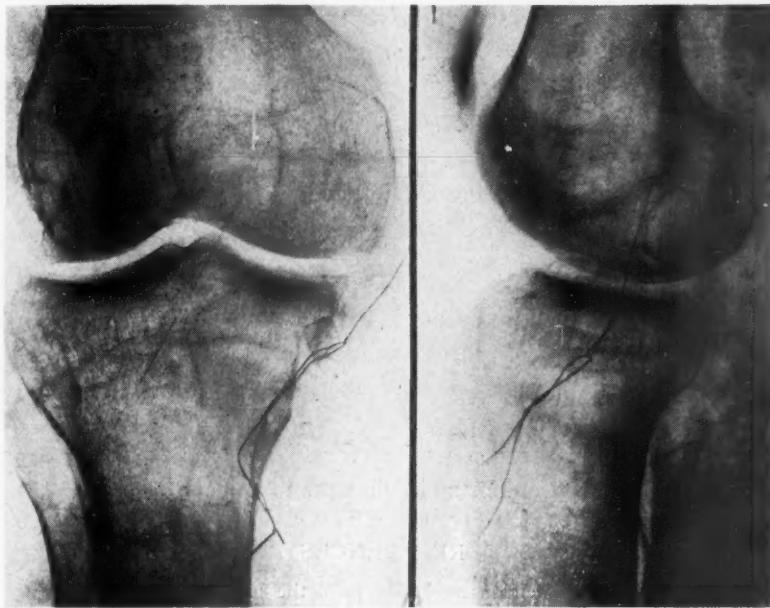

FIG. 5.—Pull-out wire fixation of the distally transplanted osseous attachment of the internal lateral ligament of the knee in Mauck's operation for the repair of this ligament. The fragment has tipped up, but not become completely displaced.

close to its attachment to the os calcis and had retracted about three inches. As the wound had occurred over two months before the operative repair the proximal end of the tendon could not be pulled down and it was necessary to split the achillis tendon and turn one-half of it down and suture this to the bone. Some months later a stitch abscess developed and some of the silk was removed. The other was a fractured patella with severe contusion of the soft tissues. This was repaired by Thompson's method and no encasement was applied. A large hematoma developed and drained about two weeks after the operation and eventually it was necessary to open the wound and remove all of the sutures. The infection was minimized with penicillin and immobilization

and the wound healed and later the scar was excised and the patella ligament was resutured to the remains of the patella and a satisfactory knee was obtained. In each of these cases the use of the pull-out wire suture with fine coapting sutures and prolonged immobilization would probably have averted the subsequent trouble.

The pull-out wire suture is useful and suitable for the fixing of ligaments to raw bone, but is not quite so suitable for the fixing of bone to bone because here rigid immobilization is desirable if the bones are to unite. Figure 5 illustrates an instance in which the internal lateral ligament of the knee was tightened by Mauck's procedure of transplanting its insertion downward on the tibia. The semitendinosus tendon was then sutured to the ligament in order to increase its strength. The No. 30 wire was pulled so tightly that the patient complained of pain under the encasement from the pressure of the wooden bar. In spite of this it is seen that the slab of bone which includes the attachment of the ligament has tipped upward a little. Fortunately, the displacement was not enough to interfere with union. But in the fixation of two fragments of bone which are expected to unite by bone such as the patella or the olecranon even a little separation may lead to delayed union or to nonunion.

CONCLUSIONS

1. Bunnell's pull-out wire suture is a valuable addition to surgical technic and has a fairly wide field of usefulness.

2. The coapting suture of fine silk and effective postoperative splinting are important parts of the method.

3. The method is not recommended for fixing bone to bone, but is especially valuable in fixing tendons and ligaments to bone.

REFERENCES

[1] O'Shea, M. C.: Severed Tendons and Nerves of the Hand and Forearm. ANNALS OF SURGERY, 105, 228–242, February, 1937.

[2] Babcock, W. W.: Ligatures and Sutures of Alloy Steel Wire. Jour. Amer. Med. Asso., 102, 1756, May 26, 1934.

[3] Bunnell, S.: Treatment of Tendons in Compound Injuries of the Hand. Journal of Bone & Joint Surgery, 23, 240, 1941.

[4] Bunnell, S.: Surgery of the Hand. J. B. Lippincott & Company, Philadelphia, 1944, P. 307.

DISCUSSION.—CAPTAIN DARREL SHAW, Martinsburg, W. Va.: Doctor Key has mentioned the advantages of stainless steel wire. We have had occasion to use it a great many times, and find it is most useful in repairing flexor tendons of the hand. We have used one of Dr. Bunnell's methods which we believe is quite useful and has certain advantages, that is, using pull-out sutures away from the line of suture or away from the tendon graft. By placing the suture at the wrist to relieve tension the tendon graft may be accurately approximated with very fine silk sutures. There is frequently difficulty in accurately approximating the tendon ends with a stainless steel pull-out wire.

Another little trick is the use of a pin-vise with a small twist drill to drill the small bones of the hand. It is simple to use and readily available. We use a fine crochet hook to pick up the wire. We have found this technic valuable in wiring bones around the face.

Dr. CHARLES S. VENABLE, San Antonio, Texas: I cannot for the life of me see why my friend Albert takes so much trouble to make an easy job hard!

Dr. J. ALBERT KEY, St. Louis, Mo. (closing): I can only answer Doctor Venable by saying that sometimes it is worth while doing things the hard way.

MUSCLE FLAP CLOSURE OF CAVITY RESULTING FROM LUNG ABSCESS*

WILLIAM H. PRIOLEAU, M.D.
CHARLESTON, S. C.

FROM THE DEPARTMENT OF SURGERY OF THE MEDICAL COLLEGE OF THE STATE OF SOUTH CAROLINA, CHARLESTON, S. C.

THE TREATMENT of lung abscess by external drainage is usually followed by a residual pleuropulmonary cavity with which there commonly is associated a bronchial fistula. The bronchial fistula may be large enough to interfere with respiration and phonation, or it may be so small as to be demonstrated only with difficulty and yet repeatedly infect the cavity, an important factor in its persistence. The natural tendency of the opening in the chest wall to close leads to pocketing with extension of the infection and the development of various complications. In the case of the smaller cavities adequate drainage and limited unroofing may lead to a satisfactory result in the nature of a depression in the chest wall with a bronchocutaneous fistula which may close spontaneously or if it persists can be closed by a pedicled muscle flap. For the larger cavities, with which this paper is particularly concerned, more radical measures are necessary. Collapse by extrapleural thoracoplasty reduces the size of the cavity but fails to obliterate it due to the bronchial fistula, the thickened parietal pleura, and anatomic considerations in the regions of the apex and the scapula. Extensive unroofing deprives the chest wall of firm support so important for proper function, necessitates the severing of a number of intercostal nerves resulting in weakness or herniation of the abdominal wall, and often fails to close the bronchial fistula. A combination of the two avoids unnecessarily radical collapse and undue severance of intercostal nerves. It effectively reduces the size of the cavity but often fails to produce its complete obliteration and a closure of the bronchial fistula.

Such residual cavities can be obliterated by the use of a pedicled muscle flap which serves as an excellent fill, and also has the property of closing bronchial fistulae. Its success is dependent upon proper preparation of the cavity, and its application is limited by the size of flap which can be mobilized in the vicinity. Accordingly, in the case of large cavities it is necessary to prepare them first by providing adequate drainage which must be maintained until closure and then by reducing their size, eliminating pocketing, and making their depths accessible for a muscle transplant. This is accomplished by a combination of unroofing and thoracoplastic measures. Treatment should be directed toward this end from the beginning.

Muscle flaps have long been used in the closure of thoracic cavities. According to Wangensteen,[1] in 1900, Abrasanhoff had sutured a pedicled muscle flap over bronchial stomas, and, in 1911, he implanted the muscle

---

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

664

directly into the bronchial opening. In 1929, Pool and Garlock[2] demonstrated experimentally that the presenting surface of the muscle becomes covered with bronchial epithelium. In a recent article Carter[3] described the use of pedicled muscle flaps in the obliteration of large empyema cavities, in some cases complicated by bronchial fistulae. He stated that the same principles apply to the cure of chronic lung abscess. Weinstein[4] reported in detail the use of pedicled muscle flaps in filling large defects following the Schede operation for secondarily infected tuberculous empyema. He stressed the fact that for a successful implant the cavity must be clean, and free of pocketing and bronchial fistulae. In 1935, Wangensteen[1] thoroughly reviewed the subject of pedicled muscle flaps in the closure of bronchopleural fistulae. Among other things, he concluded that the cavity should be obliterated at the time of closing the bronchial fistulae, that where possible it is preferable to implant the muscle into the bronchial opening rather than only suture the muscle over it, and that undue sacrifice of intercostal nerves must be avoided so as to prevent the formation of an abdominal hernia. He also observed that decortication often resulted in extensive bleeding and shock. Further historical data are given in the articles mentioned.

Once it has been decided to treat a lung abscess by external drainage, preliminary drainage should be instituted by resecting a segment of rib at the site where the abscess nearest approaches the chest wall and inserting a large mushroom catheter into the abscess cavity at the time, or some days later should the parietal and visceral pleurae not be adherent. Several weeks later adequate drainage is established by inserting a finger as a guide into the abscess cavity and resecting about four inches of two or three ribs over the dependent portion, suturing the skin to the parietal pleura. This necessitates the severing of one or two intercostal bundles, and dividing some thinned-out lung tissue. With drainage, as thus provided, the infection subsides, the patient loses his toxicity, and sputum and cough are reduced to a minimum. The size of the cavity decreases, its walls become smooth, and pockets can be recognized and opened into the main cavity. Further preparation which is directed mainly toward reduction in the size of the cavity is carried out in stages. This is accomplished in great part by the subperiosteal resection of ribs through incisions extending from the thoracotomy wound, or through separate incisions, and limited extrapleural paravertebral thoracoplasty. Unroofing is performed to the extent necessary to maintain adequate drainage, for the recognition of pockets, and for making the depths of the cavity accessible for receiving the muscle implant. The thickened parietal pleura should be excised as it interferes with collapse of the cavity and it often harbors infection which may give trouble later. Due to the fact that a greater portion of the cavity wall is formed by lung tissue there is not the extensive thickening of the parietal pleura commonly present in chronic empyema. The preparation of the cavity for the muscle implant must be carried out in stages as it is impossible to predict the amount and site of lung expansion which will occur, and, accordingly, one cannot judge the degree and the location of unroofing and rib resection which

will be necessary. This has the advantage of conserving the general health of the patient, who, in many cases, works between the stages.

The implantation of the pedicled muscle flap should be undertaken as one stage. The pectoralis major has been found most satisfactory for the upper lobe cavities and the latissimus dorsi for those of the lower lobe. The sacrospinalis muscle is particularly accessible where paravertebral thoracoplasty has been employed, however its segmental blood supply limits the length of flap which can be formed. In an incision extending from the thoracotomy the muscle is widely exposed. In the case of the latissimus dorsi or pectoralis major a large flap is mobilized and severed from its attachment to the humerus. It is thought preferable to leave the base of the pedicle attached to the trunk as this obviates a pull upon the flap with movement of the arm. On the other hand, should it be desired to leave the pedicle attachment uppermost, it still could be detached from the humerus without interference with its blood supply. The

TABLE I

SUMMARY OF CASES

	No. of Cases
Muscle flap closure—five operations	4
Healing with depression in chest wall	3
One case about ready for muscle flap closure	1
One case—recent unroofing for drainage	1
	9

muscle flap must be well mobilized, have a good blood supply, and be free of excess fat and fascia. The cavity is prepared by freeing the skin attached to the external margin and removal of the lining which is accomplished by sharp and dull dissection. This is particularly important in the proximal portion where epithelium has grown inward from the skin. While possibly not necessary in the depths where the lining is thin and pliable, it would appear to favor the adherence of the muscle. In such stripping one may encounter moderate bleeding and may open pulmonary alveoli. The cavity is then filled firmly with muscle which is held with sutures of fine catgut. The bronchial openings are generally too inaccessible or too numerous to permit of directly plugging them with muscle. The skin is closed over the muscle with provision for subcutaneous drainage. A firm dressing is applied and left undisturbed for seven to ten days. There occurs some serous drainage and at times subcutaneous emphyema. The convalescence is generally smooth and the wounds heal nicely. The bronchial fistulae are closed, the muscle gives satisfactory support to the underlying lung and cough is reduced to a minimum. The wound is supported with a chest belt for a period of weeks.

This presentation is based upon a series of nine consecutive cases of lung abscess treated by external drainage. In five of these cases, two of which are reported herewith, external drainage had been instituted prior to their coming under the care of the writer. There were no deaths in this series. A death occurred in an additional patient operated upon for lung abscess in whom the

presence of tuberculosis was not discovered until after drainage had been instituted.

Two illustrative cases are reported. In one a large cavity resulted from gangrene of apparently the whole upper left lobe. In the other there was a large cavity, mostly under the scapula, resulting from a large abscess of the left lower lobe.

CASE REPORTS

Case 1.—P. D. F. (No. 4895), white, male, age 40, was admitted to the Roper Hospital May 27, 1941. The earlier records are missing and some of the data presented was obtained from abstracts in later records. He had had 12 teeth extracted, and became ill April 13, 1941. Shortly thereafter he developed a cough productive of abundant foul sputum. He had been febrile and had lost weight. On May 17 he had coughed up some

FIG. 1.—Case 1.—December 14, 1943: Cavity just before closure.

blood, and on May 24 he had a severe hemoptysis. Roentgenologic examination showed a large lung abscess in the left upper thorax. This was drained by thoracotomy, with resection of a segment of rib. The process was so extensive that it was termed gangrene of the left upper lobe. The drainage proved to be inadequate and after a few days the thoracotomy was enlarged, with opening of pockets into the main cavity. His condition was critical for weeks. Following a hospital stay of 116 days he was discharged September 20, 1941, with his general condition greatly improved, a large upper lobe cavity, and a bronchial fistula so large that it interfered with phonation and respiration unless a firm dressing was applied. His improvement continued and he attempted work. After a few months his symptoms recurred and he was readmitted in December, 1941, with a severe

667

cough productive of foul sputum. The thoracotomy opening was enlarged and he was discharged March 12, 1942, greatly improved, but with a large cavity and bronchial fistula still present. Three days later he was readmitted on account of a severe hemorrhage from the chest wound. On this admission a thoracoplasty was performed consisting of the subperiosteal resection of segments of the second, third and fourth ribs posteriorly. Following this his general condition improved and the cavity became much smaller. At this time he came under the care of the writer. The problem was one of maintaining adequate drainage and reducing the size of the cavity in preparation for closure. On January 16, 1943, the first thoracoplasty was revised with subperiosteal resection of the posterior two-thirds of the first rib and further resection of the second and third ribs
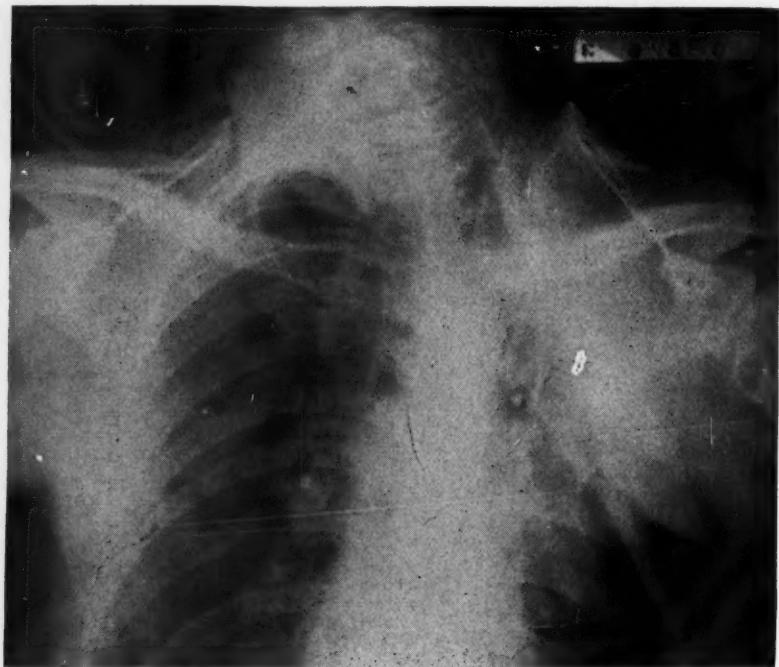
FIG. 2.—Case 1. September 29, 1945: Roentgenogram showing amount of collapse, and regeneration of ribs, which add support to the chest wall. No evidence of abscess cavity.

posterior to the thoracotomy. On February 26, 1943, further thoracoplasty was performed with subperiosteal resection of the posterior two-thirds of ribs four, five and six and the inferior angle of the scapula. On July 2, 1943, the anterior segments of ribs one and two and three were resected and the cavity was further unroofed. On December 13, 1943, the patient was admitted for closure of the cavity (Fig. 1). His general condition was good. Sputum and cough were reduced to a minimum. The chest wall opening was 4 cm. in diameter and extended to the periphery of the cavity. The cavity being conical in shape gradually diminished in size, its depth being 6 cm.; at the apex were several small bronchial fistulae. Its walls, consisting of lung tissue, were smooth and pliable. On December 16, 1944, under basal avertin and ethylene anesthesia, the skin was mobilized around the thoracotomy and an incision made anteriorly. The lateral half of the pectoralis major muscle was mobilized so as to form a pedicle with its base at its origin on the chest wall, the attachment to the humerus being severed. The lining of the cavity was then removed by sharp and blunt dissection. The peripheral portion stripped off easily; in the deeper portion moderate bleeding was encountered. This was readily controlled with

light gauze packing. The muscle flap was placed firmly in the cavity and held to some extent by several sutures of plain catgut. Skin closure was then effected, with insertion of a subcutaneous drain. A firm dressing was applied. For a few days there was some

FIG. 3.—Case 1. June 20, 1945: Eighteen months after closure of cavity.

FIG. 4.—Case 2. June 25, 1945: Cavity just before closure. Forceps lifting superior margin to show depth.

soft tissue emphysema in the pectoral region. The wound healed readily. The patient was discharged December 26, 1944. He was last examined November 3, 1945—his general condition was excellent. He had no cough or sputum. Clinical and roentgenologic examination (Fig. 2) showed no evidence of abscess cavity. The operative wound (Fig. 3) which was in the axilla and supported by the upper arm, bulged only slightly on straining.

669
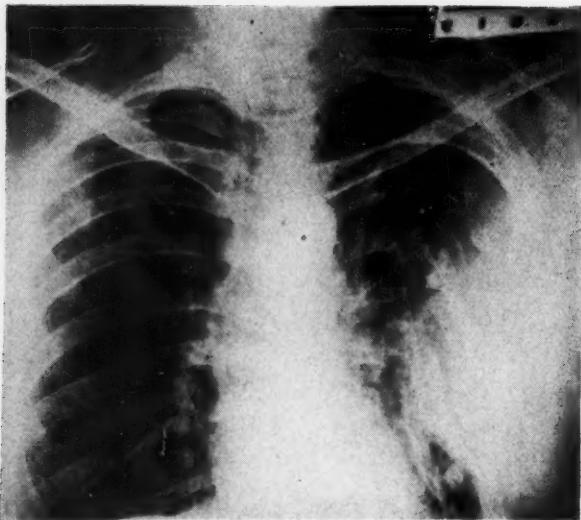
Fig. 5.—Case 2. September 19, 1945: Roentgenogram showing amount of collapse, and regeneration of ribs, which add support to the chest wall. No evidence of abscess cavity.


Fig. 6.—Case 2. September 25, 1945: Three months after closure of the cavity. Small area of lung exposed, later (November 20, 1945) this was covered by muscle flap and skin.

Case 2.—H. F. (No. 7845) white, male, age 43, was admitted to the Roper Hospital May 14, 1942. He had been taken ill eight weeks previously with a severe pain over the left lower chest, night sweats, and fever. A cough developed, which gradually became severe and productive of abundant foul sputum. Upon admission his temperature was 101° F.; he was weak and lethargic. He had lost considerable weight and had skin changes indicative of vitamin deficiency. Roentgenologic examination showed a large abscess in the lower left thorax. Sputum examination was positive for Vincent's organisms. He was given neoarsphenamin and sulfonamide therapy. Bronchoscopic drainage was performed May 18, 1942. There being no improvement of note, external drainage was decided upon. On May 26, 1942, the abscess was drained through a thoracotomy, with resection of a segment of the eighth and ninth ribs in the posterior axillary line. The cavity was described as being 8x8x10 cm. in size. He was discharged June 3, 1942, his general condition greatly improved. The thoracotomy showed a marked tendency to close, and in order to maintain adequate drainage it had to be revised by excision of thick fibrous tissue and subperiosteal resection of the ribs in the vicinity on August 28, 1942, November 6, 1942 and February 8, 1944. During this period his general condition improved, permitting him to work in between visits to the hospital.

The cavity decreased in size due to expansion of the lung and depression of the chest wall resulting from the rib resection. Its walls became smooth, the bronchial fistula continued to be large, interfering with respiration and phonation when the dressing was removed. While fibrous thickening took place in the region of the chest wall, the pulmonary walls of the cavity remained pliable. At this stage the cavity was about 5 cm. in diameter and 10 cm. deep. It was situated mostly under the scapula. On May 16, 1944, further collapse was effected by resection of the lower angle of the scapula and subperiosteal resection of the posterolateral segments of two underlying ribs. In final preparation for closure, on January 26, 1945, further unroofing was effected and the posterior segments of the seventh, eighth, and ninth ribs were subperiosteally resected. On June 19, 1945, he was admitted for closure of the cavity (Fig. 4). The diameter was about 5 cm. at the chest wall and gradually diminished toward the apex, which was about 8 cm. deep. The lining was smooth, the walls were pliable, and there was a moderate-sized bronchial fistula at the apex. On June 25, 1945, under continuous spinal anesthesia, through an incision extending anteriorly from the thoracotomy the post two-thirds of the latissimus dorsi were mobilized, and its attachment to the humerus severed. The lining of the cavity was next removed by sharp and blunt dissection. This proceeded well until the distal one-third of the cavity was reached, when coughing and respiratory embarrassment made it advisable to hasten the ending of the operation. The prepared muscle flap was firmly packed into the cavity and held in place by a few catgut sutures at the outer edge. The skin edges were then approximated in an unsatisfactory manner as inferiorly the skin had not been freed from the chest wall. A subcutaneous drain was inserted and a firm dressing applied. Except for a moderate amount of serous drainage, convalescence was uneventful. He was discharged July 12, 1945. On November 18, 1945, his general condition was good, he was free of cough and sputum. Clinical and roentgenologic examination (Fig. 5) showed no evidence of abscess cavity. On coughing there was a moderate degree of bulging in the operative region (Fig. 6). Between the skin edges there was an exposed strip of lung 3 cm. long and 0.5 to 1 cm. wide; there was no escape of air on straining. On November 20, 1945, pedicled muscle flaps of latissimus dorsi and sacrospinalis were placed over the exposed lung and the surrounding bulging area. On December 1, 1945, his temperature was normal and there was every indication of a satisfactory result.

SUMMARY

The treatment of lung abscess by external drainage is usually followed by a residual pleuropulmonary cavity, with an associated bronchial fistula. Such a cavity properly prepared by adequate drainage, unroofing and thoracoplastic

measures may be obliterated by implanting a pedicled muscle flap. Two illustrative cases are reported.

REFERENCES

1 Wangensteen, Owen H.: The Pedicled Muscle Flap in the Closure of Persistent Bronchopleural Fistula. Journal of Thoracic Surgery, 5, 27, October, 1935.

2 Pool, Eugene H., and Garlock, John H.: A Treatment of Persistent Bronchial Fistula. ANNALS OF SURGERY, 90, 213, 1929.

3 Carter, B. Noland: The Use of Muscle Flaps in the Closure of Chronic Empyema Cavities. Surgery, 3, 506, 1938.

4 Weinstein, Mandel: Closure of the Open Chest Following the Schede Operation for Tuberculous Empyema. Surg. Gynec. & Obst., 79, 148, 1944.

DISCUSSION.—DR. ROLLIN A. DANIEL, JR., Nashville, Tenn.: Dr. Prioleau has emphasized several points which are of importance regarding this method of closure of large pulmonary cavities. First, this method of treatment results in considerable deformity and some fixation of the chest wall. Second, in most cases there are multiple bronchial fistulae. Third, Doctor Prioleau has emphasized the importance of stripping away the lining of the cavity before muscle flaps are placed in it. I would like to call attention to the fact that good results can frequently be obtained by making an incision through an intercostal space or the periosteal bed of an excised rib and performing lobectomy. It may be possible to excise only a part of the lobe in order to get rid of the cavity. This can be done, as Doctor Prioleau has pointed out, following preliminary drainage of the abscess, and after the cavity has become clean. One should free the remaining lung tissue or a part of it from the chest wall. After this is done the wound can be closed and the air removed from the pleural cavity, or a tube may be left in the pleural cavity and suction applied so that the remaining lung may expand to completely fill the pleural space and close the cavity. We have done this in several patients and in three cases have found that large cavities which had been present for a long time were lined with pseudostratified epithelium.

DYSCHONDROPLASIA*

Isidore Cohn, M.D.

NEW ORLEANS, LA.

THIS PRESENTATION will be limited to a particular group of chondrodystrophies which are usually generalized and familial in character. It is not to be confused with other forms of chondrodystrophy, such as Morquio's disease. ("A rare development disease often familial in character with skeletal abnormalities and resultant dwarfism and generalized body deformity.") (Hirsch[1])

The cases under consideration have been under observation for periods varying between 15 and 25 years.

My first report was presented to the Southern Surgical at White Sulphur in 1931. ("Skeletal Disturbances and Anomalies"[2]). At that time I reviewed briefly the literature on the subject.

In 1898, Ollier suggested the name dyschondroplasia.

Sir Arthur Keith,[3] in 1919, suggested the term "Diaphyseal Aclasis" because the main incidence of the disturbance falls upon the modelling or pruning of the diaphyses.

As late as 1930 one could still find statements like the following: "The etiology of chondrodysplasia remains a mystery."

In 1928, Murk Jansen[4] advanced a theory with reference to dyschondroplasia. This theory I believe is substantiated and fully explains all of the phenomena noted in connection with observed cases. I believe that it warrants acceptance generally.

Augusta Gaskell[5] states:

"A theory that does not account for all of the facts which are involved is an inadequate solution. In order to be entirely acceptable the theory must be both sufficient and necessary. This means that the theory must fully account for the phenomena under consideration and that they cannot be accounted for on any other hypothesis."

Fisk states:

"A scientific explanation is a hypothesis which admits of verification—it can be either proved or disproved."

Gaskell further remarks:

"A hypothesis or a theory is a thing of merely temporary existence and that proof converts speculation into knowledge, and theory into accepted facts."

I believe that Jansen's theory fulfills the necessary criteria.

It must be admitted that continued investigation into natural phenomena results in the addition of fragments of knowledge which when pieced together produce composite pictures which represent the present evolutionary stage of human knowledge.

Deformities which we find in the human body are not to be accepted as accidents, but as definite evidence of retardation or dissociation processes.

The development of the human skeleton goes along in an orderly manner in obedience to a well defined plan, unless there is a factor which delays or alters the plan.

This factor may be present in the germ plasm or it may result from chemical influences exercised on the developing embryo. The hereditary factors present in the germ plasm may be dominant or recessive in character following the mendelian law.

Maud Sly, and others, have proven this beyond cavil.

Bagg[6] and Stockard,[7] distinguished embryologists, and Jansen have proven that defects are due to retardation during the embryonic period or to disturbance of the germ plasm which may be evidenced for generations.

In 1914, Potel[8] pointed out that:

"Primitive embryonic cells are endowed with almost indefinite powers of proliferation and they enclose material for several differentiations.

"When a modification of the medium or environment supervenes the plastic cellular substance endeavors to adapt itself to the new vital conditions offered to it. It develops in an atypical manner. Differentiations are diminished, modified, or even arrested. Gradually recovery ensues and the phenomena of differentiation and proliferation are restored. The momentary arrest results in a loss of equilibrium and a local modification manifests itself under the aspect of a malformation."

Such retardation in the germ plasm results in dissociation retardation phenomena which are recognized in the human body and in this instance in the form of total retardation of tubulation, lengthened metaphyses, or partial retardation of tubulation (exostoses).

In 1919, Sir Arthur Keith asserted:

"Multiple exostoses are usually placed by surgeons in the category of tumors, but a close examination of anatomical changes shows that they should be definitely placed among the disorders of growth."

Sir Arthur Keith was able to show that:

"John Hunter had recognized the modelling or pruning process by which the new bone laid down was pruned, reformed, and incorporated as an intrinsic architectural part of the cylindrical shaft."

It remained for Jansen[4] to present the theory which I believe establishes the real nature of the condition under discussion. Jansen postulates:

"Six different processes and probably more have to coöperate harmoniously in order that the bones shall attain their proper size, shape, structure, and composition, when completing their growth. These processes are resorption, tubulation, cancellation, cell division, cell enlargement, and differentiation.

"Sometimes one or more of these processes will be delayed with regard to the other processes during a shorter or longer period, and the dissociation of each of these processes evokes its own characteristic symptom.

"The clinical picture is characterized by its extreme polymorphism. In some cases only a single bone is found to be affected, and, in others the condition presents itself on both sides."

Discussing pathogenesis, Jansen says:

"During growth the epiphysis is displaced distally by the growth disk, the metaphysis is not. It stands to reason that only if tubulation keeps pace with longitudinal growth of bone, will the normal funnel-shape of the diaphysis end close to the epiphysis; whereas an approximately cylindrical area of cancellous tissue produced by the growth disk must be expected to lie between the funnel-shaped end of the metaphysis and the growth cartilage when tubulation is retarded. Hence, the conclusion presents itself that the cylindrical or barrel-shaped area between the growth cartilage and the *funnel-shaped metaphysis is caused by a retardation of tubulation* and exostoses are the result of partial retardation of tubulation. These two phenomena appear to us to be the result of a total and a partial dissociation through retardation of tubulation with regard to the other processes of longitudinal growth."

The personal observations made in this paper are based on a study of cases over a period of 25 years. In one family there is evidence of the condition in three generations, and in another I have observations in two generations. There is suggestive evidence of at least six or eight generations in one instance (Bartel and Bardwell families).

There is so much to be said and the time so limited the presentation must of necessity be brief.

1. Dyschondroplasia is an hereditary retardation phenomenon.

2. Dyschondroplasia affects the shafts of long bones particularly near the ends of the diaphysis.

3. It does not primarily affect the epiphyses. In well-developed cases the epiphyses can be shown to be normal in character, especially is this true of the lower end of the femur, the upper end of the tibia, the head of the humerus, and the lower ends of the tibia and fibula. The deformities noted in epiphyses are secondary changes.

4. One of the terms used in connection with this condition "multiple epiphyseal enchondromata" has no place in the real nomenclature of the condition.

In dyschondroplasia the shafts of the metacarpals and phalanges are affected, but not the epiphyses.

5. There is apparently no difference in the transmission to either sex.

6. The condition may be limited to a single bone, particularly the radius giving rise to the condition commonly spoken of as Madelung's deformity. The so-called Madelung's deformity was first described by Madelung at the seventh German Surgical Congress in 1878. Many cases have been presented and suggestions made as to the etiologic factors involved. A remarkable study of this condition was reported by DeWitt Stetten,[11] of New York, in 1909. He stated: "The radial curvature is due not to a disease of the cartilage, but to an irregular ossification involving principally the lower end of the shaft where the growth is most active.

675

7. Dyschondroplasia may be unilateral. In some instances I have observed a normal humerus on one side and evidence of dyschondroplasia on the other. (Note case of Iona Leich.)

8. Dyschondroplasia is progressive in its manifestations up to complete ossification of the epiphysis and the diaphysis. After full growth has been reached, there is no further evidence of progress of the condition.

9. At birth and during the first few months of life one may not find roentgenographic evidence and at a later period changes characteristic of the condition are found. (Baby Messmer.)

10. When there is a unilateral manifestation of the condition one finds the characteristic short forearm on one side and a normally developed forearm on the other.

11. True cases of dyschondroplasia manifest evidence of dissociation phenomena which may be both partial and complete.

12. Where partial retardation phenomena alone exists we note exostoses.

13. Where total retardation of tubulation occurs long or wide metaphyses are noted. In some instances in the same bone one does note both total and partial retardation phenomena, evidenced by wide metaphyses and spurlike exostoses (Fig. 1).

14. We have noted involvement of all bones laid down in cartilage but have so far not seen evidence of the condition in bone laid down in membrane such as the skull.

15. It is remarkable to note that in most instances there is little or no disturbance of function of the joints and comparatively little pain complained of by any of the patients I have seen.

16. The condition should not be considered a disease. It is pathologic in the sense that there is a lack of harmony in the various processes which have to do with normal bone growth.

17. There is no indication to operate unless the individual mass interferes with joint function.


FIG. 1.—Dotted lines indicate normal tubulation. Irregular areas outlined indicate failure of resorption and tubulation. Broad metaphysis can be noted. Clear spaces indicate delay of cancellation.

18. It is important to avoid surgery during the early period of growth as operation may favor shortening of the limb by premature ossification at the epiphyseal line.

Fig. 2.—Case I: J. C., — Dyschondroplasia.

Figs. 3-4. Case I: J. C., — Dyschondroplasia.

19. Only pedunculated masses which interfere with motion or function should be removed.

A very brief abstract of examination in each instance is made in this report.

Case 1.—Jennie Chappetta (Case 7 of original report).

This patient has been followed continuously since 1921. She has had one full term pregnancy. (Delivery was effected by cesarean section because of the marked distortion of the pelvis). She has suffered no inconvenience. There has been no limitation of her activities.

Pictures taken in 1945 indicate that the sites from which some of the larger masses were removed have shown no evidence of recurrence or further progress of the process (Figs. 2, 3 and 4).

Case 2.—Annette Messmer (daughter of Jennie Chappetta) shows the stigma in the right femur, and a node on the eighth rib (Fig. 5).

Note: In an attempt to obtain evidence in previous generations, I have not been able to obtain positive information. The grandfather has no evidence of skeletal deformity.

The mother is one of 11 children and four of these have polycythemia vera, familial type. The grandfather of the baby stated that he had three brothers and two sisters; his father was tall and his mother was "short," but he has never noted in any of the family evidence of deformities of any kind.

Bardwell Family—

In the family about to be reported six cases in two generations have been personally observed.

From the history there is evidence that several other members of these two generations have the same skeletal character.

FIG. 5.—Case 2: A. M., (daughter of J. C.) —Dyschondroplasia.

Case 3.—Mrs. Lewis Bardwell Nott, age 45, height 5 ft. 1.5 inches.

The right forearm is shorter than the left. There is loss of the carrying angle; and there is a deformity of the wrist with deviation of the hand to the right.

There is a large bony prominence on the shaft of the right humerus just below the head; a similar though larger mass can be palpated on the left humerus.

There is no limitation of motion of either knee, but on the inner aspect of the right thigh there is a large bony prominence which extends down about three inches and can be

tion

port.

term
rtion
f her

that
arger
evi-
ss of

ghter
na in
eighth

dence
been
The
keletal

n and
famil-
stated
sters;
was
any of
f any

orted
been

dence
these
skele-

e; and

ow the
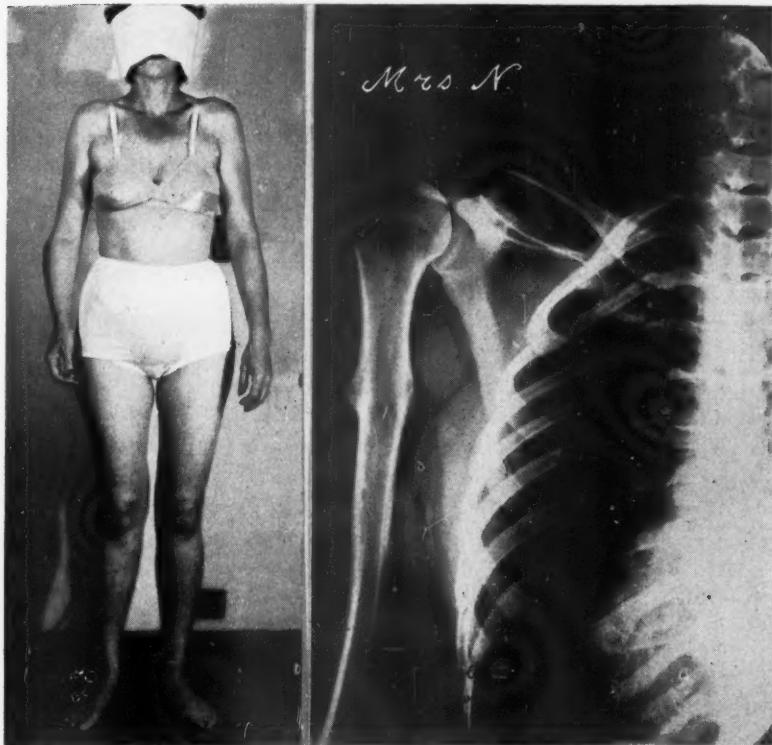
right
can be

FIG. 6-7.—Case 3: Mrs. L. B. N., — Dyschondroplasia.

FIG. 8-9.—Case 3: Mrs. L. B. N., — Dyschondroplasia.
679

palpated in the popliteal space. On the left fibula the bony masses are more prominent than those on the right (Figs. 6, 7, 8 and 9).

Case 4.—Lewis Nott, age 9, son of Mrs. Bardwell Nott, was examined in 1932, at which time there were skeletal retardation phenomena noted symmetrically on the long bones of the upper and lower extremities.

Note: The mother stated that he has not been incapacitated in any manner as a result of the condition.

Case 5.—Eugene M. Bardwell, age 26. He is one of 11 children.

Patient states that his condition has never interfered with his activities. Right forearm is shorter than the left. There is a loss of the carrying angle on the right side.

There is no limitation of motion of the joints of the upper extremities.

He has large bony prominences on the ribs, particularly the fourth, fifth, and sixth ribs on the left side.

Lower Extremities: There is loss of symmetry of the two legs. There are bony masses palpable on the long bones of both lower extremities.

"Roentgenologic examination, October 30, 1945, (No. 23084) of the right shoulder and arm, the right forearm, the right knee, and the left ankle reveals findings characteristic of metaphyseal aclasis (hereditary deforming dyschondroplasia)" (Figs. 10, 11 and 12).

Case 6.—Earl Bardwell, age 28. First seen in September, 1932. Patient was next seen on October 23, 1943, when he returned to the office at my request.

This young man was inducted in the Army on April 26, 1945, and discharged for disability July 4, 1945. He stated that: "Most all of the boys in the Bardwell family have the same thing. My mother is normal, all of the Bardwell family are involved."

Examination.—October 23, 1945: There is loss of the carrying angle; the forearms are short and there is a marked bowing.

FIG. 10.—Case 5: E. M. B.
—Dyschondroplasia.

There is loss of symmetry of the shoulder girdles, there is a tilting of the pelvis; on the inner aspect of the knees there are marked bony bosses, particularly on the right side, and on both tibia there are large, nodular, painless bosses. There is no limitation of motion of either ankle.

"Roentgenologic examination, October 22, 1945, (No. 22719) of the right shoulder, forearm, knee, and ankle, and of the left hip reveals multiple manifestations of metaphyseal aclasis (hereditary deforming dyschondroplasia)." (Figs. 13, 14, 15 and 16).

Case 7.—Huey Bardwell, age 15 (October 30, 1945).

In spite of the fact that he has dyschondroplasia he is able to play football and has never been handicapped in any way. Height 4 feet 10 inches.

Examination: Short forearm (right). Both forearms show marked deformity but more marked on the right—there is a radial deviation of the hand. Bosses are seen as well as palpated on the lower end of the radius and ulna. There is no limitation of motion of either wrist or elbow. Bony prominences on the upper end of both humeri.

Palpable mass over the lower end of the ribs, particularly the right side. Lower extremities are short, bony prominences above and below both knees. There is no limitation of motion of either knee in spite of the fact that the mass on the inner side of left knee is about the size of a small orange. There is no limitation of motion of either ankle, but the bosses are prominent on the lower end of the fibula on the left.

"Roentgenologic examination, October 30, 1945, (No. 23087) of the right forearm and knee and the left leg reveals findings characteristic of metaphyseal aclasis (hereditary deforming dyschondroplasia). Irregular calcareous deposits in the soft-tissue component

FIGS. 11-12.—Case 5: E. M. B., — Dyschondroplasia.

of an osteochondroma arising from the medial surface of the proximal tibial shaft indicates that this part of the tumor is predominantly cartilaginous and interval studies to determine its rate of growth are advised." (Teitlebaum) (Figs. 17, 18, 19 and 20).

Case 8.—Sybil Bardwell, age 10 (October 30, 1945). Diagnosis: Dyschondroplasia.
Examination: Right forearm shorter than the left. Both shoulders are prominent. Bosses noted on the right, particularly below the pectoral groove. Madelung's deformity, with the deviation of the hand to the radial side. There is no limitation of motion of any of the joints of the upper extremities. On the left forearm there are bosses on the radius and the ulna. On the ribs there are large bosses. There are bony masses on the left above the condyles which extend down into the popliteal space. There are large bony prominences on the upper end of the tibia and fibula and along on the tibia and fibula of both legs just above the ankles.

681

FIG. 13.—Case 6: E. B., — Dyschondroplasia.
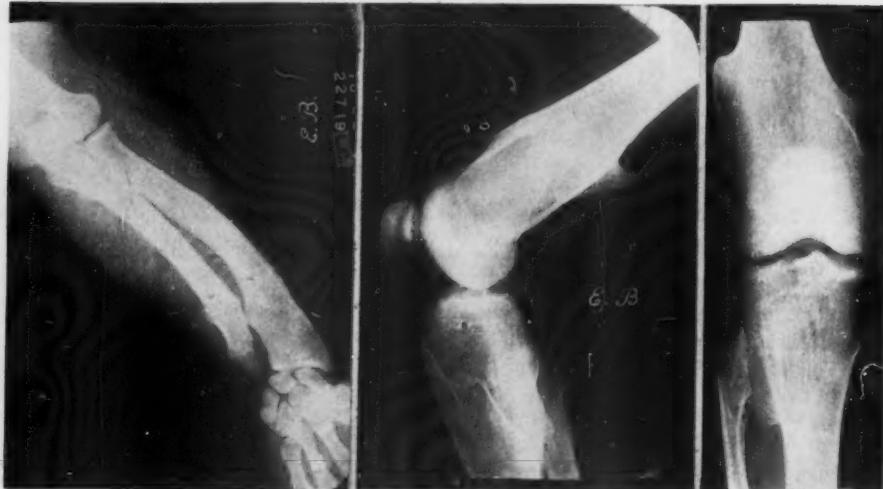
FIGS. 14-15-16.—Case 6: E. B., — Dyschondroplasia.
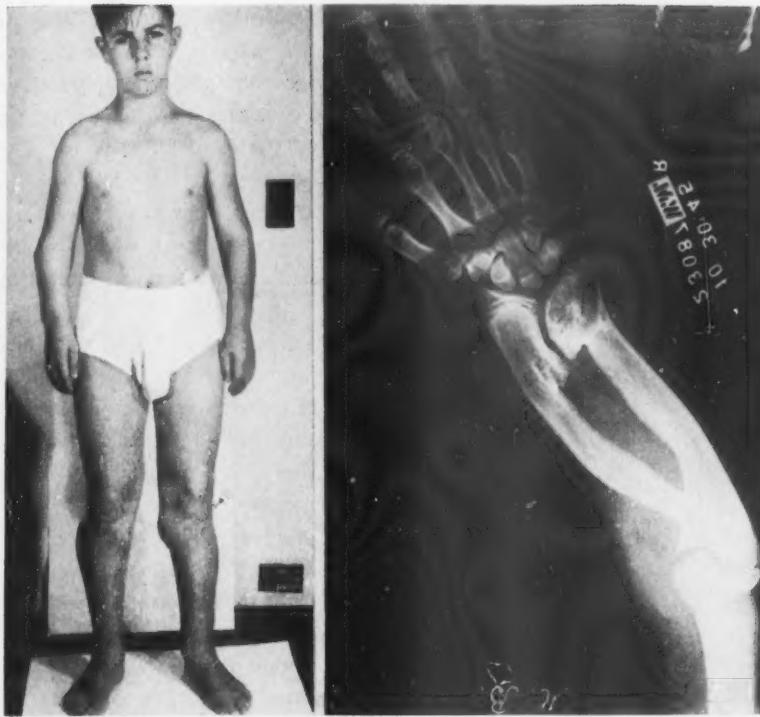
FIGS. 17-18.—Case 7: H. B., — Dyschondroplasia.

FIGS 19-20.—Case 7: H. B., — Dyschondroplasia.

Roentgenologic examination, October 30, 1945, (No. 23085) of the right shoulder and arm, the right forearm and the left knee reveal changes typical of metaphyseal aclasis (hereditary deforming dyschondroplasia) (Figs. 21, 22, 23 and 24).

Case 9.—Mrs. E. A. A., age 32, was first seen in 1926, and reported as Case 6 of the original report. This is the only case in the series in which the condition was limited to one bone—the radius.

A follow-up roentgenogram, (No. 23350) November 5, 1945, indicates that there has been no progress of the deformity since complete fusion of the epiphysis and diaphysis. "Examination of the left forearm reveals a deformity characteristic of metaphyseal aclasia (hereditary deforming dyschondroplasia)" (Fig. 25).

Case 10.—Iona Leiche, age 7. September 10, 1932: Patient brought here after mother had been informed that her child had a peculiar bone disease but that nothing could be done.

Examination.—Child seems to be well-developed. Left upper extremity is shorter than right. The forearm is bowed. The deviation being to the ulnar side. The forearm itself is much shorter. All of the fingers of left hand present bosses on at least two phalanges. Lower extremities are apparently same length. Crest of ileum on left side seems larger than right. Right shoulder: Head of humerus rotates without limitation of motion. No masses palpable over humerus, radius or ulna.

Fig. 21.—Case 8: S. B., Dyschondroplasia.

Figs. 22-23-24.—Case 8: S. B., — Dyschondroplasia.

684

FIG. 25.—Case 9: Mrs. E. A. A., Dyschondroplasia limited to one bone—radius.
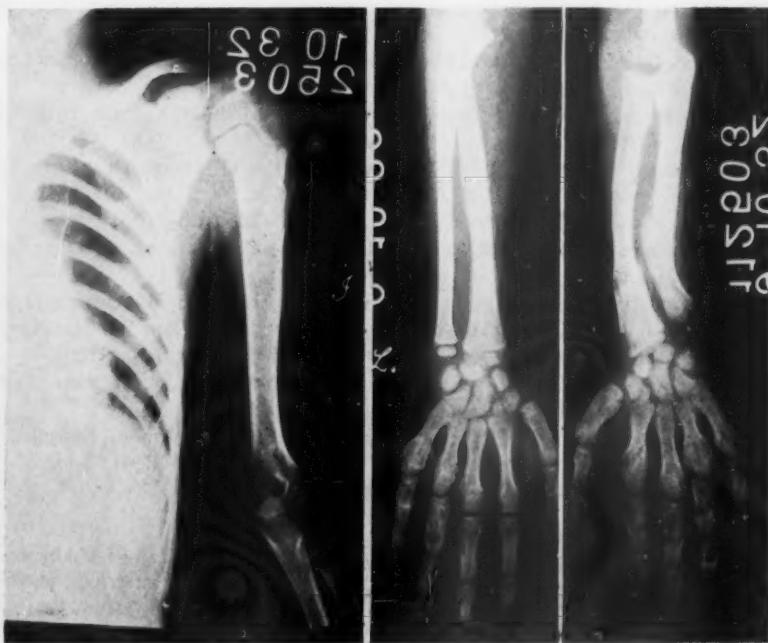
FIGS. 26–27.—Case 10: I. L., Dyschondroplasia—Asymmetric nature of condition noted in radius and ulna of the two forearms. Marked involvement of metacarpals and phalanges.

685

Fifth metacarpal: This presents large bony mass at its lower end. There seems to be a fusiform enlargement. There are hard bony bosses on the phalanges on all except thumb and index finger.

Left side: Head of left humerus larger than right; large bosses palpable on it.

A number of bosses are palpable on lower third of radius and ulna. Ulna is shorter than the radius. Bosses are on phalanges and metacarpals, larger on left than right.

Roentgenologic examination, September 9, 1932, (No. 1112503): "There is observed well-defined dyschondroplasia here which seems decidedly more extensive upon the left side in the upper extremity than in the right upper extremity. Fairly large areas of cartilage can be observed in the phalanges of the little and ring finger of the right hand, as well as the small and proximal phalanx of the middle finger. The metacarpals of the same three fingers on the same hand, likewise show the same type of change. In the arm and forearm, however, upon the right side no such island can be observed. In the left upper extremity the phalanges of all fingers, the metacarpals of all fingers, the radius and the ulna, as well as the upper end of the humerus and the scapula show rather extensive islands of cartilage, and in all cases these appear nearer the epiphyseal line than in the middle portion of the bone." (Figs. 26 and 27).

COMMENT: This case illustrates very well the asymmetric nature sometimes noted. The radius and ulna on one side normal in appearance; there is marked involvement of the radius and ulna on the other.

The involvement of the metacarpals and phalanges are probably as well noted in this case as any I have ever seen.

BIBLIOGRAPHY

[1] Hirsch, I. Seth: Generalized Osteochondrodystrophy. Journal of Bone & Joint Surgery. 19, 297–313, 1937.

[2] Cohn, Isidore: Skeletal Disturbances and Anomalies. Southern Surgical Transactions. 44, 485–521, 1931.

[3] Keith, Sir Arthur: The Nature of the Structural Alterations in the Disorder known as Multiple Exostoses. Journal of Anatomy, 54, 101, 1919–20.

[4] Jansen, Murk: Dissociation of Bone Growth. Jones Birthday Volume, 1928. Oxford University Press.

[5] Gaskell, Augusta: What is Life? Published by Charles C. Thomas, 1928. pp. 27–33.

[6] Bagg, N. J.: American Journal of Anatomy, 43, No. 2., 187, 1929.

[7] Stockard, C. R.: American Journal of Anatomy, 28, 116, 1920-21.

[8] Potel, G.: Congenital Malformation of the Limbs. Rev. de chir., 49, 283–325; 625–648; 822–858, 1914.

[9] Anton, I. Joseph, Reitz, George B., and Spiegel, Milton B.: Madelung's Deformity. ANNALS OF SURGERY, 108, 411–439, 1938; Brinsmade, William B.: Madelung's Deformity of the Hands: Case Report. ANNALS OF SURGERY, 47, 794, 1908.

[10] Claiborne, E. M. and Kuntz, T. G.: Madelung's Deformity; Case Report. Radiology, 27, 594–599, November, 1936.

[11] Stetten, DeWitt: Idiopathic Progressive Curvature of the Radius or So-called Madelung's Deformity of the Wrist. (Carpus Varus and Carpus Valgus) Journal of Surgery, Gynecology, and Obstetrics, 8, 4–31, January, 1909.

DISCUSSION.—DR. IRVIN ABELL, Louisville, Ky.: Doctor Cohn has kindly consented to my showing some slides of a patient who came to us for an acute appendicitis. He presented such a multitude of skeletal tumors that after his recovery from the operation for appendicitis a study was made. Some of the films are shown today, not so much because of the rarity of the lesion as because of the number and extent of the tumors; 91 being revealed on the roentgenograms. The case conforms to the pattern of hereditary

deforming chondrodysplasia, in that numerous tumors were present, accompanied with skeletal deformities which arose between childhood and maturity and involved bones developed from cartilage. The component parts of each bony system, with the exception of those developed from membrane, showed such involvement.

Case Report.—The patient, a man, age 25, was one of ten children. He stated that three of his brothers (not available for examination) had similar tumor masses and deformities, none as numerous or as large as his own. The remaining brother and his five sisters showed no visible evidence of the disease. There was a history of similar tumors in the father, but none had occurred in the mother, nor in the older generations of the family, so far as he knew. His first bony deformity was noted by his parents when he was one year old. At the age of 11, he was admitted to the Children's Hospital, the record of which showed that in June, 1925, bony tumors were removed from the left outer malleolus and from the lower end of the left ulna. Microscopic examination confirmed the clinical diagnosis of benign osteochondroma. According to the record, roentgenologic examination at that time showed multiple exostoses of nearly all the long bones (slides). The metacarpals, the metatarsals, and the phalanges showed the same type of growth, the total number of tumors being 91.

TRAUMATIC OSTEOMYELITIS:
THE USE OF SKIN GRAFTS—PART II*

SUBSEQUENT TREATMENT

Lt. Colonel Robert P. Kelly

Captain Louis M. Rosati, and Captain Robert A. Murray

Medical Corps, Army of the United States

FROM THE SURGICAL SERVICE, ORTHOPEDIC SECTION, ASHFORD GENERAL HOSPITAL, WEST VIRGINIA.

The initial article of this series[1] presented the technic and results obtained in skin grafting to hasten healing of the saucerized osteomyelitic wound. The procedure outlined consisted of thorough removal of all involved bone and soft tissue, application of a pressure dressing, and, four days later, skin grafting the resulting granulating wound. In a representative group of cases the results were: 24 per cent excellent, 28 per cent good, 24 per cent fair, and 24 per cent poor. Only in the last group did skin grafting have to be repeated in order for healing to pursue a more rapid course than otherwise could have been expected.

Healing of the osteomyelitic wound in this fashion leaves one with the problem of subsequent treatment of the patient. Obviously, two courses may be pursued—that of no further treatment, and that of replacing the free skin graft in some way. What follows is based on an analysis of the fate of 126 free skin grafts employed to heal saucerized osteomyelitic wounds (Table I). In some instances of failure two or more grafts were applied successively to the same wound.

Discharged with Free Graft Intact.—The vitality of free skin grafts is threatened on every hand. The thinner the graft and the poorer the initial take, the greater is this tendency. Congestion, attended by capillary extravasation and edema formation, favors activation of latent infection either primarily, or secondarily through the medium of peripheral phlebothrombosis and thrombophlebitis. Either pure congestion, or infection activated thereby, takes its toll of grafts. Impaired venous return, temporary or permanent, is the rule on resuming ambulation after the osteomyelitic wound has been healed by free skin grafting. Irritant effects of dirt, even on normal skin, need only be mentioned to be appreciated. Depleted in accessory organs, split-thickness grafts are highly sensitive to irritants. Poorly aerated in cavities, opposing skin-grafted walls coming into contact are prone to maceration and smegma formation. Unfavorable hygiene is avoidable in proportion to the visibility and accessibility of the skin graft, granted the patient's zeal for cleanliness. We have undoubtedly discharged some patients with free graft intact, who would have been better off had replacement been performed.

TABLE I

FATE OF 126 HEALED DERMATOME GRAFTS IN SAUCERIZED OSTEOMYELITIC WOUNDS

Not replaced.. 28
Replacement.. 98
    By abdominal tubed-pedicles... 47
        Successful... 6
        Failures... 4
        Incomplete... 27
        Planned.. 10
    By direct abdominal pedicles... 13
        Successful... 12
        Failures... 1
    By crossed-legged pedicles... 11
        Successful... 7
        Failures... 4
    By local pedicles... 13
        Successful... 5
        Failures... 8*
    By excision and closure... 6
        Successful... 5
        Failures... 1
    By excision, muscle transplant closure................................... 4
        Successful... 1
        Failures... 2
        Undetermined... 1
    By excision with iliac chip implants..................................... 10
        Successful... 2
        Failures... 8

* Includes cases with iliac bone implants.

TABLE II

NONCAVITIES: METHODS OF REPLACING DERMATOME GRAFTS

Comparison of various site—coverage combinations

Coverage

Site	Local Closure	Local Pedicle	Open Pedicle	Closed Pedicle	Total
Arm	2 — 100		1 — 100	1 — 100	4 — 100
Forearm			10 — 80	1 — 0	11 — 72.7
Thigh					
Leg	1 — 100	8 — 86.5	11 — 72.7	3 — 66.66	23 — 73.9
Pelvis	3 — 66.66				3 — 66.66
Total	6 — 83.3	8 — 86.5	22 — 69.5	5 — 60	Grand Total 41 — 75 6

Key

No of Cases
—
% Success

689

Replacement of Graft.—Replacement of free grafts has been effected in a number of ways. The most obvious and simplest is that of excision of the graft and closure of adjoining tissue. Hereafter this technic is referred to as *local closure.* The greater the proportion of soft-tissue involvement to bone involvement, and the less the ratio of width of the original wound to the cir-

FIG. 1-A
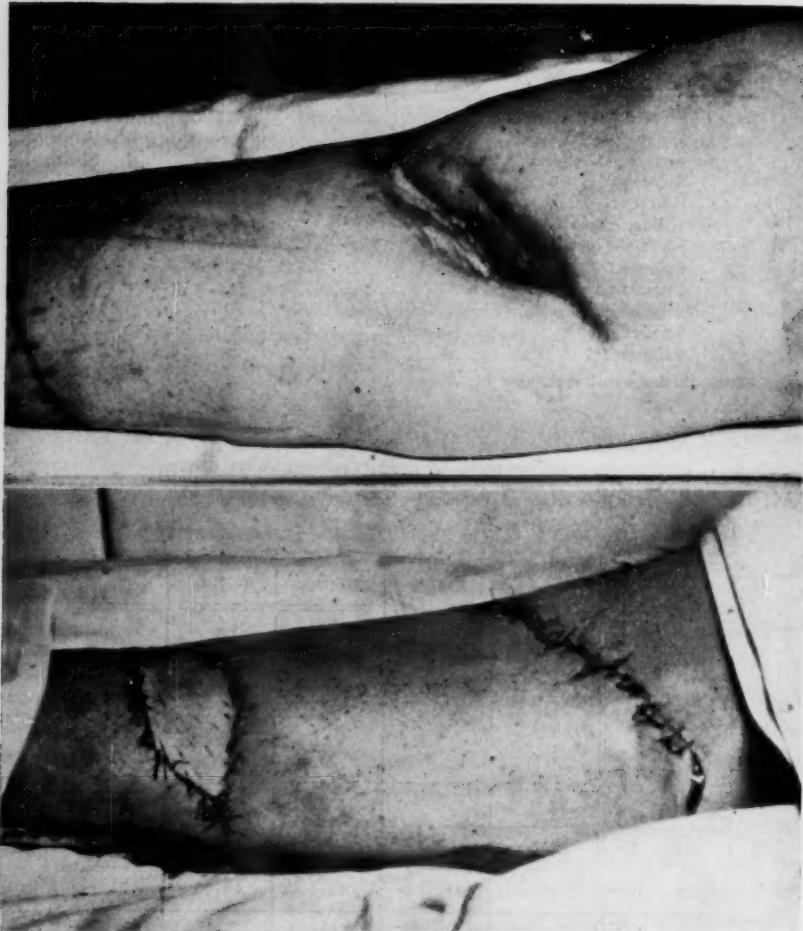
FIG. 1-B

FIG. 1.—(A) Local pedicle. (B) Iliac chips were introduced as fillage coincident with resection of free graft, shift of local pedicle, and skin grafting the newly denuded donor gap. Failure resulted.

cumference of the part involved, the more apt is this method of replacement to succeed. Superficial closure is often the minor problem. Obliteration of deep dead space incident to bone and soft-tissue loss challenges one's ability to bring into play a technic satisfying basic principles of surgery. To the extent of
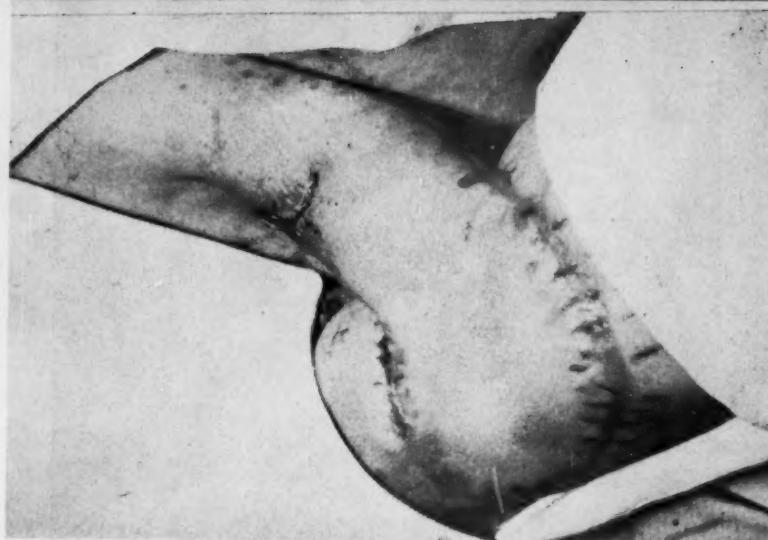
FIG. 2-A

FIG. 2-B

FIG. 2.—(A and B) **Skin graft** for replacement and open pedicle in place. Note the following: **Cavity existing required no fillage for dead space;** scar wide because of tension; scar of partial severance of flap preliminary to final application—only rarely necessary in abdominal pedicles and not so in this instance.

691

Fig. 3-B

Fig. 3.—(A) Open pedicle. This cross-leg pedicle, based distally, was used to replace a dermatome graft.
(B) Resulting donor site and replacement shown.

success in solving the problem of dead space, results are good. Sometimes local closure of *skin only* is effected, and other technics are employed for filling dead space.

Relaxing incisions long have been employed to permit tensionless closure of wounds. The double-pedicled skin flap shifted from local sources to effect closure is the next logical step. Combined with skin grafting of the resulting denuded area, it has been employed in a number of instances. If the flap be single-pedicled, perhaps having been prepared in advance, it will fall more readily into superficial dead space. Again, the site from which the pedicle was shifted may be filled in by free skin graft. This is sometimes referred to as a

FIG. 4.—Closed pedicle. Advantage over direct abdominal pedicle lies in cleanliness of former.

rotation flap. For the purposes of this discussion, each of the above procedures is considered a local pedicle (Fig. 1).

A free graft too large for the above methods may be replaced in the upper extremity by a direct abdominal pedicle,[2] and in the lower extremity by a single-pedicled cross-leg[3] flap. Either of these methods (Figs. 2 and 3) is referred to hereafter as an *open pedicle*.

Where for any reason the free graft cannot be replaced readily by any one of the above means, a tubed-pedicle may be employed, or resort may be had to a "paddle" extension of a tubed-pedicle. These methods are referred to below as *closed pedicles* (Figs. 4 and 5).
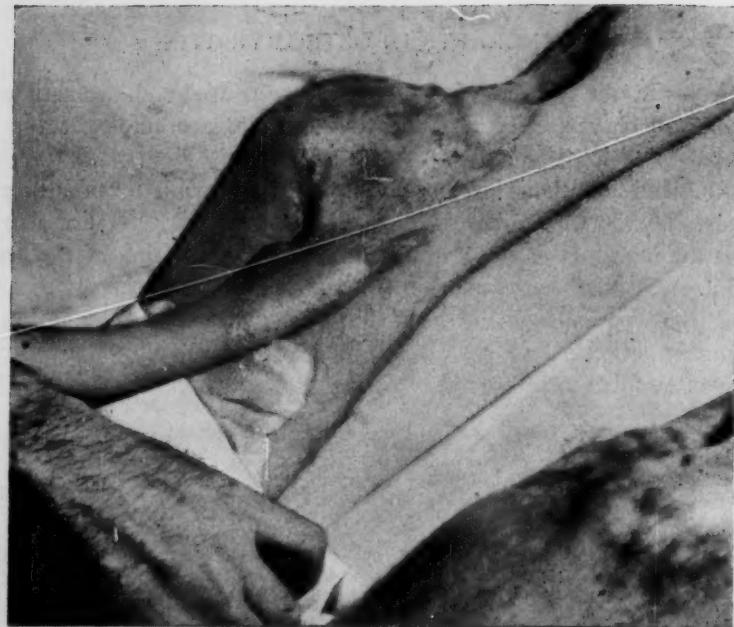
FIG. 5-A

FIG. 5-B

FIG. 5-C

FIG. 5.—(A and B) Late steps in transference of tubed-pedicle to replace a free graft lining a cavity. Fat transplanted with the tube was used to fill potential dead space within the cavity. (C) Healing nearly complete. Ulceration from pressure of dressing over bony prominence.

694

Replacement problems fall into two groups—those in which the free-grafted surface is flat (Table II) ; and those presenting a cavity (Table III). In the former, one has but to satisfy the precepts of plastic surgery, and success is a foregone conclusion. In the latter, the hazards attendant upon technical inability to perform good skin plastic surgery are increased by the risk attendant upon introduction of material to fill the cavity. We shall refer to the skin as *"coverage,"* and to the additional material required for cavity obliteration as *"fillage."*

As might be anticipated, our results have been in proportion to the complexity of the surgical problem presented, and to a lesser extent to the vulner-

TABLE - III

-CAVITIES-
METHODS OF REPLACING DERMATOME GRAFTS
COMPARISON OF VARIABLE COVERAGE-FILLAGE COMBINATIONS

COVERAGE

	LOCAL CLOSURE	LOCAL PEDICLE	OPEN PEDICLE	CLOSED PEDICLE	TOTAL
ILIAC BONE CHIPS	3 / 66.66	5 / 20		2 / 0	10 / 33.3
FAT				3 / 100	3 / 100
MUSCLE PEDICLE	6* / 66.66	1 / 100			7 / 71.4
TOTAL	9 / 66.66	6 / 16.66		5 / 60	GRAND TOTAL 20 / 55

(FILLAGE — left axis label)

KEY
No. of CASES / % SUCCESS

* INCLUDES 2 LESIONS TREATED BY SECONDARY CLOSURE WITH MUSCLE TRANSPLANT AS FILLAGE...

ability of blood supply inherent in the coverage selected. Table I illustrates the type of coverage applied to various anatomic locations when cavities were not a problem. The direct abdominal pedicle flap has been a most dependable procedure. The margin of safety appears greater in this method than in any other. After transfer of relatively large abdominal pedicles, closure of the resulting wound is possible.

The technic of cross-leg flaps, as described by Ghormley,[3] has proved reliable in our hands. The importance of removing fibrotic tissue from the deep surface of the pedicle at the time of its transference cannot be overemphasized. Of still greater importance is application in advance of plaster encasement, both to the donor and to the recipient leg. Through appropriate windows, surgery

for transference of the flaps is performed. When this is completed, struts of plaster and wood bind the legs together. Thus, one prevents twisting, turning and tension so fatal to pedicles. Although we have received informal reports of difficulties from applying a dermatome graft beneath the pedicle prior to its transfer, this procedure has been most gratifying to us and has led to no difficulties with either the dermatome graft or the pedicle itself.

Attempting to force by pressure or suture any type of pedicle graft into a cavity invites disaster. In dealing with cavities, two groups of substances have chiefly been employed for filling dead space: (1) Bone as free graft. (2) Locally available substances, principally fat and muscle, as pedicle grafts. The former has found more extensive usefulness. Knight and Wood[4] have reported considerable success with its employment, and since it is most often bone substance which is to be made up, it has been the logical material to use. When readily available, and when no need existed for increasing bone strength, pedicle grafts as fat or muscle have been employed in several instances.

Our success with bone as fillage has been deplorably poor. Iliac chip replacement was employed in four cases of related type not included in this series, in each instance with success. In one, simultaneous saucerization and filling of the resulting cavity with iliac chips was performed, with *per primam* healing resulting. In a second, a local pedicle covered iliac chips introduced four days after saucerization and packing of the wound with plain gauze. Again healing was prompt, without drainage. In the remaining two, iliac chips were grafted into recently healed osteomyelitic wounds, with general and local recovery uneventful. Technic of bone surgery employed in the two groups of patients was comparable. Success in the latter four patients presenting comparable risk of infection, suggests that our failures are not explainable on the basis of inadequacies in technic of bone surgery.

Faced with an overwhelming proportion of failures when iliac bone chips were used as replacement, we have employed increasingly many abdominal tubed-pedicles. Thus, we can introduce fat into the cavity as fillage simultaneously with skin coverage. Results have been excellent in replacing by this means free skin grafts occupying bone cavities. Grafting bone into the cavities later should present no special risk.

At present, Captain E. R. Zaglio, a member of the Orthopedic Section at this hospital, is investigating the applicability of physiologically inert foreign substance as fillage. Thus far, there appears to be some promise in this method.

CONCLUSIONS

A considerable proportion of free skin grafts employed to hasten healing of saucerized osteomyelitis wounds require no replacement. When outlook for permanence of a free graft is otherwise good, one should use skin thick enough to contain skin accessories. Little difficulty will be met by those experienced in plastic surgery technic in replacing the skin grafted on a flat surface. Replacement of free skin grafts lining cavities has posed a considerable problem to us. We have failed where others have succeeded in using iliac bone chips to fill

cavities occupied by a free graft undergoing replacement. The search for a substitute or intermediary procedure is being continued.

REFERENCES

[1] Kelly, Robert P., Rosati, Louis M., and Murray, Robert A.: Traumatic Osteomyelitis; The Use of Skin Grafts, Part I. ANNALS OF SURGERY, **122**, 1–11, July, 1945.

[2] Brown, J. B.: Surface Repair of Compound Injuries. Journal Bone & Joint Surgery, **26**, 448–454, 1944.

[3] Ghormley, R. K., and Lipscomb, P. R.: The Use of Untubed Pedicle Grafts in the Repair of Deep Defects of the Foot and Ankle; Technique and Results. Journal Bone & Joint Surgery, **26**, 483–488, 1944.

[4] Knight, M. P., and Wood, George O.: Surgical Obliteration of Bone Cavities Following Traumatic Osteomyelitis. Journal Bone & Joint Surgery, **27**, 547–556, 1945.

REPAIR OF BONY DEFECTS ASSOCIATED WITH OSTEOMYELITIS*

Guy A. Caldwell, M.D.

New Orleans, La.

FROM THE DIVISION OF ORTHOPEDICS, TULANE MEDICAL SCHOOL, THE SECTION ON BONE & JOINT SURGERY, OCHSNER CLINIC AND CHARITY HOSPITAL IN NEW ORLEANS, LA.

CHRONIC, localized hematogenous osteomyelitis continues to be a difficult surgical problem. Infection is harder to control in bone than in other connective tissues. Bone is rigid, its vessels cannot contract or expand and its cavities do not collapse. Even if infection has finally been arrested, the surrounding bone is abnormal because of diminished circulation, increased density, loss of valuable organic material and isolated tiny cavities containing dormant organisms.

The advent of chemotherapy and the development of new procedures in the management of compound fractures during the war gave rise to the hope that osteomyelitis might be eliminated. As the end-results of treatment become better known, it is evident that chemotherapy is not the entire answer to the problem and that well-directed surgical measures must continue to be our mainstay for the treatment of chronic osteomyelitis.

At the Tulane University School of Medicine and Charity Hospital in New Orleans a project, under the direction of the Subcommittee on Wounds and Burns of the National Research Council, was undertaken to evaluate various surgical procedures for the repair of bony defects associated with chronic osteomyelitis. The objects were to promote union of compound fractures with bony defects and infection and to obtain closure and healing of the infected bony cavities in chronic hematogenous osteomyelitis.

At the outset certain essential differences between localized and hematogenous osteomyelitis were recognized. The localized type associated with compound fractures usually occurs in the shafts of the long bones in adults. Because of the fracture, perfect immobilization is impossible and motion of the fragments prolongs the infection. Frequently, small fragments have been lost leaving an infected bony defect. In the chronic stage the bone-forming elements have ceased to function, the ends of the fragments are relatively avascular, the marrow cavity is sealed and the periosteum is destroyed. The process, however, is confined to the immediate site of fracture, and the remaining portions of the shaft and the extremities of the long bone are approximately normal.

In contrast, chronic hematogenous osteomyelitis is seen most often as extensive involvement of most of the shaft and one extremity of a long bone in children. Frequently, there are multiple foci and flat bones may also be

---

involved.   The lesion in adults is usually a recurrence of the old childhood infection but may occur as an initial attack.   In the latter instance, infection is usually in the shaft of a long bone and the course of the disease is not the same as that observed in childhood because of the difference in the structure and blood supply of adult bone.   However, the appearance of the bone in the chronic stage is much the same as in the recurrences following an initial attack in childhood.

The microscopic sections of bone from localized osteomyelitis cannot be differentiated from those of the hematogenous type.   The problems are essentially the same except for the sharp limitation of the bone reaction in the localized variety.   In both types there may be general depletion, extensive scar formation and diminished local blood supply.   The bone itself is often devoid of normal periosteum and is brittle, and relatively avascular.   Granulating cavities draining poorly or containing sequestra are common.   Mixed infections are the rule rather than the exception.

The sulfa drugs and penicillin are usually effective against the staphylococci and streptococci present in the bone cavities, but their effectiveness is impaired by diminished blood supply to the part and by the presence of mixed infection, cavities and sequestra.   Chemotherapy, therefore, plays a limited rôle in the elimination of infection and final healing and its use must be supplemented by surgical measures to remove dead bone, flatten cavities and obtain good soft part coverage of the remaining bone.   In addition, in compound fractures it is essential to immobilize and fix the fragments and provide some stimulus for new bone formation.

The surgical measures employed have been simple modifications of recognized standard procedures for dealing with the soft-parts and bone.   Complete removal of the scar and sinus (when present) is the first step.   The deep as well as the superficial portions must be widely excised until healthy skin, fascia and muscle are encountered.   In like manner, the dense, sclerotic, "scarred" bone should be removed with a chisel until healthy, bleeding bone appears.   After dead bone and fibrous tissue filling underlying cavities have been removed, the cavity should be shaped to the best possible advantage for coverage with soft-parts.   It is always desirable to cover the raw bone with muscles and full-thickness skin; if both are not available, full-thickness skin may suffice.   In order to cover the area adequately it is often necessary to split the fascia over adjacent muscle compartments and permit the muscles from either side to bulge out over the bone.   In some cases it is necessary to sacrifice a muscle by dividing it at the musculotendinous junction and freeing the belly far enough to permit it to swing as a pedicle graft into or over the defect.   In freeing the muscle for this purpose its blood and nerve supply must be carefully preserved.

Skin coverage usually can then be accomplished by undermining and sliding the skin on either side.   If this cannot be done without tension, the undermined skin may have to be split at some distance from the wound margins or made into a pedicle graft on one side.   Again, care must be exer-

cised to retain abundant blood supply to the flap or pedicle by observing the ratio of three to one between length and width of the graft and planning it to retain a sizable nutrient vessel. The principle to be observed throughout the operation is to get healthy bleeding bone surfaces covered with healthy, bleeding soft parts but without tension.

Immediate closure without drainage is followed by primary healing in about 90 per cent of the cases, but only about 60 per cent remain permanently healed. Failure to heal is attributable to incomplete removal of scar and sclerotic bone (which is sometimes impossible in cases of chronic hematogenous osteomyelitis), to inadequate blood supply to bone and soft-part coverings, or to too great tension on the skin margins. Recurrence of infection is usually prevented if adequate coverage and good blood supply can be preserved.

If the infected bone cavity is large enough and so located that it weakens the bone for weight bearing, consideration must be given to filling the cavity with a bone graft and obtaining adequate soft-part coverage thereafter. Knight and Wood[1] have apparently solved this problem in cases of localized osteomyelitis by a three-stage procedure. In the first stage sequestra are removed and the cavity is prepared for the second stage, viz., application of a split-thickness skin graft, and a third stage which includes excision of the split-thickness graft, filling the cavity with bone chips and covering them with full-thickness sliding or pedicle graft of skin. Their early results in 23 published cases have been excellent. Application of a similar procedure to cases of hematogenous osteomyelitis may present a greater problem but certainly should be tried.

Old, compound fractures with nonunion and draining sinuses have been treated while still draining by excision of scar and sinus and performance of a step-cut procedure on the bone ends followed by closure. Internal fixation is not used. The inch of shortening is not a serious disability and the resultant laxity of the tissues caused by shortening usually permits closure of the skin without tension. In the leg, osteotomy and overlapping of the fibula is usually a necessary adjunct.

Other cases with loss of substance, 1 to 3 cm., have been treated in the presence of active infection by an approach to the lateral aspect of the tibia that is some distance from the scar and sinus. In such cases the periosteum and muscles are simply pushed laterally and a long graft taken from the opposite tibia is forced alongside between the lateral face of the tibia and the fibula. It may or may not be fastened to the tibia with screws. The sinus and scar are not disturbed. Dr. H. Page Mauck[2] recently demonstrated a number of cases treated by this procedure with resultant closure of the sinus and bony union in a high percentage. Various operative procedures, as previously described, have been used in 43 cases of chronic osteomyelitis of long bones. In all of these penicillin was given two to three days prior to operation and for seven to ten days afterwards. There were 21 cases of localized osteomyelitis of which 80.4 per cent healed per primam but only 61.8 per cent remained healed after 5 to 12 months. Sufficient time has not

elapsed to give the percentage of cases in which bony union has developed. There were 22 cases of hematogenous osteomyelitis (nine tibias, eight femurs and five humeri). Of these, 81 per cent healed primarily but only 63 per cent remained perfectly healed after 5 to 12 months. Analysis of failures to heal in both groups indicates that incomplete removal of scar and bone and too great tension in making skin closures were the important causes.

SUMMARY

Well directed surgical measures to remove dead bone, flatten cavities and obtain good soft-part coverage of the remaining bone continue to be our mainstay for the treatment of chronic osteomyelitis. Penicillin and the sulfonamides play only a limited rôle in the elimination of infection and final healing. Of 21 cases of localized osteomyelitis treated by various surgical procedures supplemented by chemotherapy, 80.9 per cent healed *per primam* but only 61.8 per cent remained healed after 5 to 12 months. Of 22 cases of hematogenous osteomyelitis, again, 81 per cent healed primarily and 63 per cent remained healed after 5 to 12 months.

REFERENCES

1 Knight, M. P., and Wood, G. O.: Surgical Obliteration of Bone Cavities Following Traumatic Osteomyelitis. J. Bone & Joint Surg., 27, 547–556, October, 1945.
2 Mauck, H. P.: Personal communication.

DISCUSSION.—DR. WILLIAM DARRACH, New York, N. Y.: I should like to express my deep appreciation for the invitation to be present at this meeting. The reputation of the Southern Surgical Association for advancement of knowledge as well as for delightful entertainment has been outstanding for many years, and they have more than lived up to this reputation.

I should like to emphasize one point brought out that we as civilians have to face, and the men in the army and naval hospitals have to face; that is, the filling in of defects following gunshot or other wounds of the lower extremities, more especially the tibia. There is an underlying principle they have mentioned, which Champ Lyons brought out several years ago, and others have since—that is, the preparation of the patient prior to operative work in the final stage of treatment to fill in these defects. I think one of the most graphic descriptions of preparation of the patient comes from the Bible:—

"A sower went out to sow his seed; and as he sowed some fell by the wayside; and it was trodden down and the fowls of the air devoured it. And some fell upon a rock; and as soon as it was sprung up, it withered away, because it lacked moisture. And some fell among thorns; and the thorns sprang up with it and choked it. And other fell on good ground, and sprang up, and bore fruit an hundred fold. He that hath ears to hear let him hear."

I think we can also get good advice from our wives as they work in the garden; they prepare the bed before they put in the seed. It seems to me if we are going to prepare any form of bone graft or filling-in of a cavity, we must pay attention to preparation of the patient from both a general and local standpoint. It is interesting to see how reparative bone processes will improve after a few transfusions; building up the patient from all points of view, general as well as local preparation, will determine very largely the success of our efforts.

MAJOR-GENERAL NORMAN T. KIRK, Washington, D. C.: I am always glad of an opportunity to express my gratitude to the medical profession for what it has done to save the lives of the men who fought this war. I am particularly glad to be able to say this to a group of specialists, for specialists were utilized in this war as they never were utilized in previous wars. The Medical Corps, like other branches of the Army, was

chiefly made up of civilian components. We of the Regular Army formed the nucleus of the Corps, it is true, but the war was fought and won by civilians, and the outstanding record of the Medical Corps was made possible by the civilian physicians who constituted the great majority of its personnel. Incidentally, I am not unmindful of the contribution made by the physicians who did the work at home. I realize, very fully, how greatly their task was increased by the withdrawal of so many of their number into the Service.

Wounded casualties in the Army amounted to approximately 571,000, of whom about 360,000 were returned to duty overseas. About 25,000 of our wounded died, approximately 4 per cent. I am told on good authority that the German losses in this category amounted to 8 per cent, and that during the winter campaign of 1944-45 about 13 per cent of their wounded died as the result of their injuries.

In my own mind there is no doubt why the percentage of American deaths from wounds was so much lower than the German percentage. I was in North Africa in April, 1943. I was in Italy the following year. What happened in the Medical Corps between those two dates is the explanation.

On the occasion of my first visit to the Mediterranean Theater of Operations, every medical officer in the Corps was treating patients according to his own plans and policies. Some of the methods were very good. Others, to put it bluntly, were very poor. On the occasion of my second visit, every patient in the Theater was being treated according to the definite regimen instituted under the leadership of Colonel Churchill. Phases of military surgery and the missions of each echelon in respect to them had been clearly established. The first phase, initial surgery, was performed near the Front lines. The second phase, reparative surgery, was performed in the Base Hospital behind the lines. The third phase, reconstructive surgery, was performed in the Zone of Interior.

It was this system of surgery, strictly adhered to, which gave the American Army the lowest percentage of deaths from wounds ever achieved in any Army. Before this method was developed, to give you a single illustration, the incidence of osteomyelitis following compound fractures was relatively quite high. Initial débridement was often imperfectly done, and delayed wound closure was infrequently practiced. Patients were put in plaster and they arrived in this country with infected, malodorous wounds, the end-result of which was deformity.

Then the plan was changed. Initial surgery was thoroughly carried out in Field and Evacuation Hospitals. Primary closure was not permitted. It was impractical to secure precise reduction of fractures in the Forward areas, and the attempt was therefore not made. Instead, plaster designed primarily for transportation from the Forward Hospital was applied and the patient was transferred to the General Hospital in the Base. Once he reached the General Hospital, accurate reduction was achieved by manipulation or skeletal traction. The compounding wounds, if they were clinically clean, were closed by suture or skin graft, usually within five to ten days after wounding.

Patients were held in the Base Hospital until early callus formation would prevent displacement of their fractures during transportation. Those with fractures of the femur were held for eight to ten weeks, and sometimes longer, in skeletal traction. Then, in a lag-period, when no definitive surgical procedure was necessary, they were transported to the Zone of Interior.

Let me call your attention to several special points. In the first place, please note that it was the gross appearance of the wound which determined the time for delayed suture or skin graft, not bacteriologic studies. I yield to no one in my admiration for the bacteriologist in his place, but I thank God he was not available for use in this connection.

In the second place, while great advances have been made in reconstructive bone surgery, I do not myself classify a sliding bone graft of the tibia among them. I sometimes hear surgeons remarking that they can perform such grafts and "get away with them." Perhaps so, though not in most cases, and I do not believe, regardless of the outcome, that this method represents good surgery. Furthermore, we learned in the course of the war, and it is regrettable that we had to learn it over again at the patient's expense—we knew it 25 years ago—that any kind of graft is useless unless it is put into a properly prepared bed.

Finally, let me say a word about chemotherapy. We owe much to the studies of the National Research Council in this field, and the systemic administration, first of the sulfonamides and later of penicillin, undoubtedly saved many lives and made much

extensive surgery possible. I think we can hope for even more remarkable results in some diseases from streptomycin. But I do want to emphasize that it was good surgery which saved lives. The thorough excision of devitalized tissue was absolutely essential. Chemotherapy was merely an adjunct. The early reports from Pearl Harbor completely misled us. They were not duplicated in a more extensive experience. We promptly learned that dusting a wound with sulfanilamide, or giving sulfanilamide by mouth in the form of pills, did not permit a disregard of sound surgical principles. That was another thing we learned the hard way, but eventually we learned it.

All our badly wounded soldiers—between 260,000 and 280,000 of them—have been brought back to the General Hospitals in this country. The men with osteomyelitis, the men with bilateral amputations, the men who need multiple plastic operations and multiple hand surgery and other equally serious procedures have come home from the war. Their need now is primarily for specialized treatment. The fighting war is over, but the Medical Corps has still a job to do. That it will be finished with the same competence with which it was begun, I have not the slightest doubt.

Dr. Duane Carr, Memphis, Tenn.: Over a number of years it has been my privilege to observe a reasonable number of patients with osteomyelitis of the bones of the thoracic cage. It is a problem on which Dr. John Alexander and I wrote some 10 or 12 years ago, and at that time we advocated adequate surgical débridement of the tract followed by primary closure in those cases of tuberculous osteomyelitis uncomplicated with pyogenic infection. However, many of these cases of osteomyelitis of the sternum, ribs or clavicle were primarily tuberculous but complicated with pyogenic infection, following incision and drainage of the original abscess, resulting in a chronic mixed-infection.

In our 46 cases a fairly large percentage of those treated with primary closure reopened. Many of our earlier mistakes, I believe, have now been overcome. Our practice now is the complete excision of all infected tissue and bone followed by primary closure with a pressure dressing, even in the mixed infected cases. Penicillin before and after operation is a helpful adjunct, but we found our principal mistake formerly was in failing to carry out a more complete excision. Osteomyelitis of the thoracic cage complicated by tuberculosis has a tendency to develop sinuses boring through adjacent tissue and leading to other abscesses at some distance from the site of the original infection. Many of these sinuses are so small as to escape detection in the operative wound. I have, therefore, routinely used the injection of one per cent methylene blue under gentle pressure before the excision is begun and, to be complete, the excision must include all stained tissue. A spot less than one millimeter in diameter may be a sinus leading to an abscess elsewhere or even osteomyelitis of adjacent bony structures.

The use of methylene blue, the complete excision of all diseased tissues, primary closure without drainage, a pressure dressing, and penicillin before and after operation, have resulted in 100 per cent permanent closure in the limited number of patients so treated in the past two years.

Dr. Charles S. Venable, San Antonio, Texas: I have enjoyed the very scholarly presentation of Doctor Caldwell and am for once not in any disagreement. I think, however, there are some few very salient factors that may be taken in their order in doing secondary rearrangement and rehabilitation following destructive osteomyelitis. General Kirk "rang the bell" when he said you cannot expect sulfa and penicillin to take all the cockroaches out of the kitchen. It takes plenty of good surgery, as we learned in the last war. Let us grant this has been done and we come to the defects following osteomyelitis. I think we must give the time-element a sufficient waiting period to know that no further necrosis is beginning in the bone ends. That gives an expression of the blood supply, because if this is insufficient union will not take place. When this has been decided—the condition of the tissues and even spots of regeneration of bone—the remaining periosteum must be removed and the bone ends denuded entirely to assure the blood supply to both ends of the graft. This must be firmly fixed, because if there is movement fibrosis will occur at one or the other end and union will not take place. I think soft-tissue closure is almost as important because, after all, blood supply is what it takes; closure of the soft-tissue so closely and completely about the graft that it may pick up blood supply between its ends. A dead space there is an exposure to defeat.

DR. ROBERT W. JOHNSON, JR., Baltimore, Maryland: My introduction to chronic osteomyelitis took place at the hands of Doctor Halsted. In those days we were sterilizing these cavities after radical excision and saucerization by pure carbolic acid, followed by alcohol, and lavage with at least ten gallons of bichloride solution. With his meticulous technic the field was cleaned and redraped, and we transferred to an entirely clean instrument table and set-up. Even after this heroic procedure the blood clot would break down and the wounds show the same organism as before. That experience sold me on the idea that the wound of an osteomyelitis could not be sterilized by any local method, and later experience with Dakin's solution, maggots, sulfa compounds, and penicillin locally have only served to confirm this. We have, however, an entirely new help in systemic chemotherapy, working on the "patient-side" rather than the "doctor-side" of the wound. This is the greatest advance that has been made, and this change in method and point of attack has been shown splendidly by the essayists.

I think that Doctor Caldwell's slides on the pathology, with which he introduced his remarks, are the crux of the situation. He shows that he is dealing with the pathologic tissue and not the cavity. The cavity is one thing, the pathologic tissue in the wall of the cavity is another, and this latter is what we must keep in primary consideration. We are dealing with tissue, ill-supplied with blood at best, which has little chance to become hyperemic, and with bone trabeculae and scar-filled spaces it has little power of healing. This is why bone cavities differ from other scars in healing ability. New blood supply is simply unable to reach the site of the disease. While this is true in acute osteomyelitis, it is ten times more so in the chronic type. All the measures that have been suggested are of value—grafts of skin, flaps, muscle flaps, *etc.,* in that they reduce the area to be filled in and/or bring with them new vascular supply to aid in the process. Major Kelly's cases, which we were privileged to see yesterday, are even more convincing than his excellent paper of today.

DR. FREDERIC W. BANCROFT, New York, N. Y.: I would like to emphasize the difference in the healing of fractures of bone and ordinary connective tissue. Bone consists of two elements: a cellular element and a matrix which has low metabolic needs and can persist for a considerable time without the presence of cellular elements. When a bone transplant is imbedded, sections of this bone two or three weeks after operation will show the absence of osteoblasts in the bone spaces. As time goes on, if graft is to succeed, there will be revascularization through the vessels entering the Haversian canals and about these vessels will appear numerous bone cells in the canaliculi. If revascularization does not occur in the bone graft and cells do not reappear, the bone eventually atrophies, or if infection be present it is cast off as a sequestrum. I believe that we see the evidence of bone atrophy in late fractures of the graft when the transplant is not laid in a vascular bed.

These observations are important clinically because they show us that we must place a graft in an area free from scar tissue and infection if we expect the graft to persist and become again living bone, which occurs by a gradual process of creeping replacement.